CR 72000
File
10-34

[redacted]

FACILITY FORM 602

N66 29292	
(ACCESSION NUMBER)	(THRU)
147	1
(PAGES)	(CODE)
CR-72000	32
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

[redacted]

GENERAL DYNAMICS

Convair Division

GPO PRICE $ ________

CFSTI PRICE(S) $ ________

Hard copy (HC) 4.00

Microfiche (MF) 1.00

ff 653 July 65

[redacted]

A2136-1 (REV. 5-65)

CENTAUR TANK CORROSION TESTS AND X-RAYS

Report Number GD/C-BNZ65-032
1 August 1965

Contract Number NAS3-3232

Prepared by Test Evaluation

Approved by M R Barlow

M. R. Barlow
Manager
Systems Engineering
Centaur

GENERAL DYNAMICS
CONVAIR DIVISION
San Diego, California

The Tank Corrosion Prevention Program was under the direction of M.R. Barlow 951-0, Systems Engineering Manager.

Those contributing to the compilation of data and preparation of this report were as follows:

R. F. Bausback	951-4	Test Evaluation
J. A. Crush	141-4	Process Control Labs.
C. A. Navarette	966-4	Centaur Stress
L. Norris	952-1	Systems Analysis
J. K. Hildrenbrand	951-4	Test Evaluation
W. M. Sutherland	572-1	Materials Research
P. J. Swanson	952-1	Systems Analysis
D. Treadway	572-3	Materials & Process Test Service

Information and assistance were also obtained from the various technical, design, reliability, quality control and production organizations.

Additional copies of this document may be obtained by contacting Centaur Resources Control and Technical Reports Department 954-4, Building 26, Kearny Mesa Plant, San Diego, California.

FOREWORD

This report documents procedures for monitoring, controlling, and preventing spotweld corrosion on present, as well as future, Centaur tank structures.

The report is published under Contract NAS3-3232 to satisfy the requirements of ECP 55-604, as directed by Change Orders 219, 245, and 326.

29292

SUMMARY

It has been determined that tank corrosion can be deterred or prevented. This is accomplished in the following manner:

a. Eliminate the corrosive elements from tank fabrication processes.

b. Fabricate the tank under stringent clean conditions and provide protection from contamination during storage.

c. Apply WD-40 corrosion inhibitor to the outside surfaces of the tank structure and to parts and assemblies as early in fabrication as is compatible with future manufacturing operations.

The effectiveness of these preventative measures has proven successful as displayed by the low quantity of corrosion found on Centaur Tanks 7D, 8D and 9D, the first Centaur tanks manufactured using revised cleanness procedures.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

TANK CORROSION STUDY

1.1 INTRODUCTION

1.1.1 PURPOSE. The purpose of this task is to monitor, control, and prevent spotweld corrosion in existing Centaur tanks as well as future production tanks.

Corrosion initiation in future Centaur tanks will be minimized by eliminating corrosion inducing materials from the manufacturing process. Replacement processing materials will be certified for use only after adequate testing. A back-up program using ammonia gas was considered for use in the event corrosion initiation approached an unacceptable level. However, it was found to be unfeasible.

1.1.2 OBJECTIVE. To satisfactorily conduct this corrosion study, it was necessary to achieve the following objectives:

a. Determination of the sources and causes of the corrosion.

b. Development of methods to inhibit present and future corrosion to Centaur tanks.

c. Development of acceptance standards for corroded tanks.

d. Documentation and evaluation of data acquired for application to future corrosion problems.

To meet these objectives, it was necessary to accomplish the following tasks:

a. Phase I - Re-examine X-rays and develop trend charts.

b. Phase II - Provide supplementary X-ray data and integrate with Phase I charts (effort to continue through 12D, AC-15).

c. Phase III - Determine causes, effects, and means of preventing corrosion by laboratory tests and analysis (effort to continue until approximately 1 October 1965).

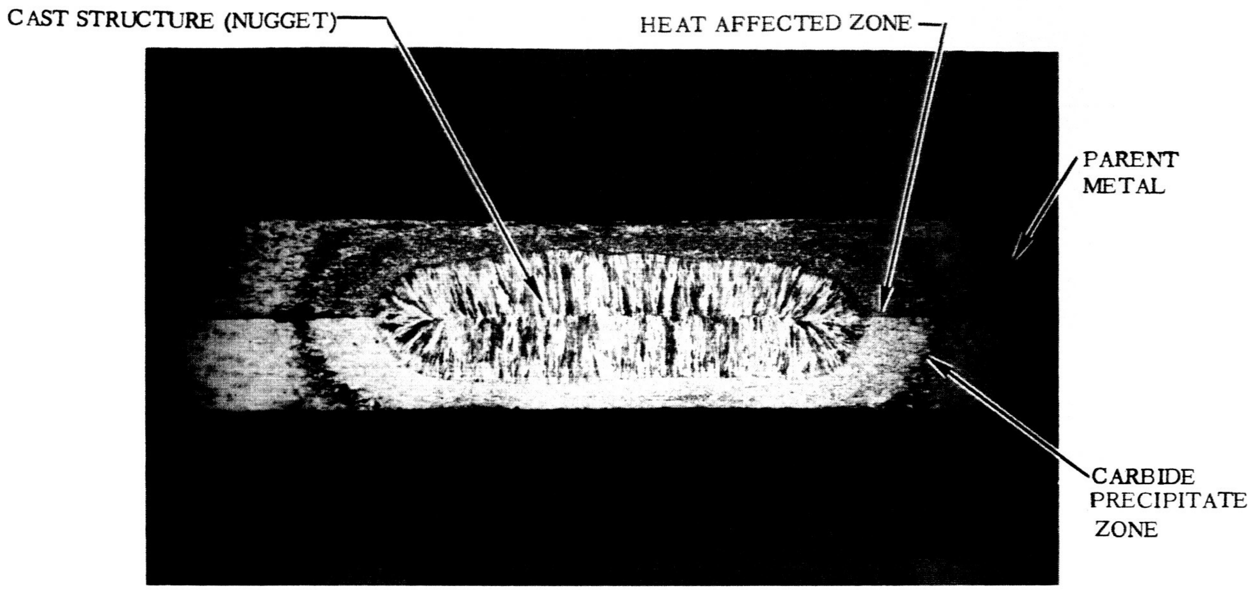
d. Phase IV - Effect changes in Centaur tank construction standards to inhibit substances inducing corrosion.

As supplementary X-ray data is obtained and summarized (Phase II) it will be added to this report.

Phase III laboratory tests are incomplete as of this date. Tests include (1) continued investigation to determine a LO_2 compatible corrosion inhibitor and (2) determination of the effects of corroded spotwelds on the static, fatigue, and sustained load capability of structural tank joints. Test results will be placed in this document as soon as they are available.

1.1.3 BACKGROUND INFORMATION. Radiographic inspection is routinely employed to verify the quality of each spotweld during subassembly fabrication and during Centaur final tank assembly operations. X-rays verified that upon completion of each major subassembly operation all spotwelds were free from corrosion defects. Subsequently, the subassemblies were stored until final tank assembly. Following the cryogenic pressure proof test, the tank was subjected to a post-cryo radiographic inspection. Analyzing post-cryo X-rays of 2D (AC-6) and 3D (AC-7) indicated spotweld cracks and pits were developing. Re-X-rays confirmed that the pits and cracks had increased in both quantity and size. Samples of the affected spotwelds are shown in Figures 1-1 and 1-2.

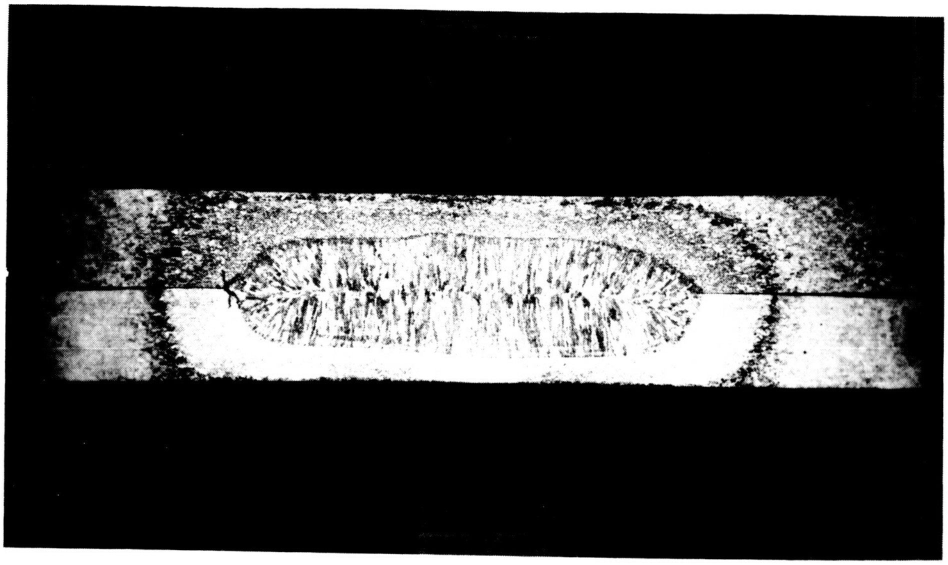
As a result of discovering these defects in the Centaur spotwelds by radiographic inspection, General Dynamics/Convair was directed by NASA/Lewis Research Center by NAS3-3232 Change Orders 219, 245, and 326 to conduct a corrosion study, which established the requirement for this document.



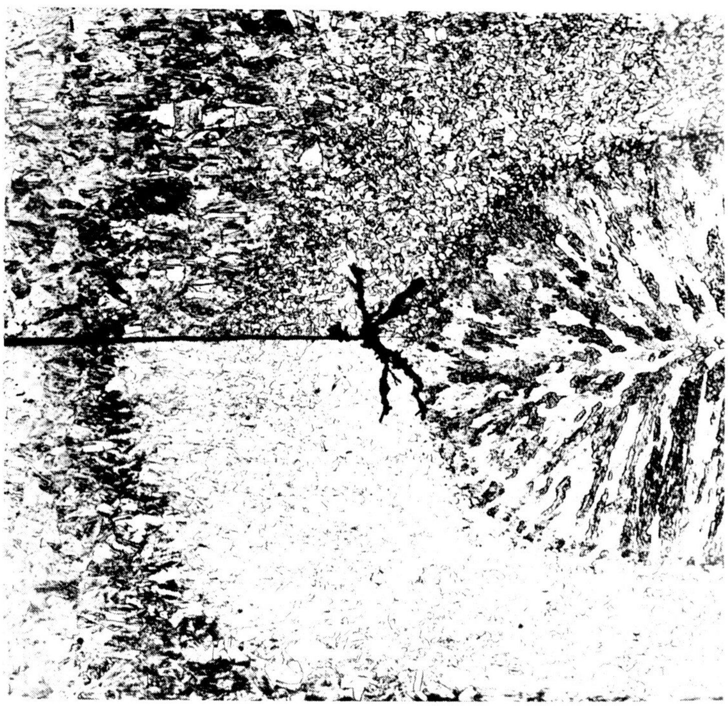
PHOTOMICROGRAPH OF THE CROSS-SECTIONED SPOTWELD
(MAG. 25X; ELECTROLYTIC OXALIC ACID ETCH).

PHOTOMICROGRAPH AT A HIGHER MAGNIFICATION (100X) OF THE LEFT SIDE
OF THE SPOTWELD SHOWN ABOVE (ELECTROLYTIC OXALIC ACID ETCH).

Figure 1-1. Spotweld Cross-Section Showing Corrosion Pit



PHOTOMICROGRAPH OF A CROSS-SECTIONED SPOTWELD SHOWING CORROSION CRACK (MAG. 25X; ELECTROLYTIC OXALIC ACID ETCH).



PHOTOGRAPHS AT A HIGHER MAGNIFICATION (100X) OF THE SPOTWELD SHOWN ABOVE

Figure 1-2. Spotweld Cross-Section Showing Corrosion Crack

SECTION II

CORROSION CHARACTERISTICS

2.1 ORIGIN OF CORROSION

2.1.1 TYPES. The corrosion in Centaur tanks, which has been detected by radiographic inspection, has been observed almost exclusively between the faying surfaces adjacent to spotwelds. This corrosion usually appears as either pits in metal caused by corrosion or cracks formed by corrosion combined with stress in the metal. The corrosion may result from three processes. They are:

a. An acid solution in contact with the metal which attacks the metal directly.

b. An electro-chemical process in which the metal is removed by galvanic action.

c. Stress corrosion where the corrosion is initiated by stresses within the metal in the presence of an electrolyte.

2.1.2 WELD CONFIGURATION. A cross-section of a spotweld shows four distinct areas where corrosion may occur. They are:

a. Parent metal unaffected by the welding.

b. The cast structure or actual weld nugget formed by the molten metal.

c. The heat affected zone.

d. The carbide precipitate zone formed by the precipitation of chromium carbides upon cooling.

Figure 1-1 shows a typical cross-section of a spotweld with these areas denoted.

2.1.3 CORROSION ZONE. Most of the corrosion at the spotwelds begins at the carbide precipitate zone. This may be the result of intergranular corrosion resulting from sensitization. Occurring principally in austenitic stainless steels when they are heated in the range of 900 to 1400°F, sensitization results from precipitated chromium carbides at the grain boundries, chromium depletion in zones adjacent to those boundries, and a difference in solution potential between the center of the grains and their outer chromium zones (This assumes a solution capable of serving as an electrolyte is present at the spotweld).

2.1.4 FORMATION. The conditions described in paragraph 2.1.3 result in pits and cracks as shown in Figure 1-1 and 1-2. These branching cracks have been found to be both intergranular and transgranular and are similiar in appearance to cracks produced by stress corrosion. They appear to originate as a pit and form cracks due to stresses set up during metal cooling, or could originate as micro-cracks, produced during welding operation, which were attacked and opened up by a corrosive fluid in the faying surface. This fluid may be one of the corrosive processing fluids listed in Table 3-3 which may have become trapped between the faying surfaces before or after the sheets were spotwelded. Corrosion may also have been initiated by non-corrosive solutions combining with salt or other dry corrosive elements, which settled from the atmosphere during tank buildup, forming electrolytes or corrosive solutions.

2.2 THEORY OF ELIMINATING CORROSION

2.2.1 ELIMINATING CORRODENTS. The most effective way to prevent corrosion is to keep corrodents and moisture from tank surfaces, especially from between faying surfaces where entrapped moisture can form electrolytes. Corrodents may be introduced by inadequate cleaning prior to assembly, or by spillage during subsequent manufacturing operations, such as cleaning, marking etc. Moisture can become entrapped between the faying surfaces by remaining on the surface prior to attachment due to incomplete drying or wiping, or may be drawn into the faying surfaces by capillary action. Maintaining a dry surface should prevent corrosion since a fluid must be present in order to form an electrolyte for galvanic action.

2.2.2 NEUTRALIZING CORROSIVE SOLUTION. In order for any type of corrosion to take place, a corrosive solution or electrolyte must be present. A neutralizing agent such as ammonia or a water displacement type of corrosion inhibitor may be used. The ammonia may neutralize acid electrolyte forming an alkaline electrolyte. Alkaline electrolytes would form hydroxides with ferrous metals which adhere to the surface and retard further corrosion.

Water displacement agents such as WD-40, due to their low surface tension and high affinity for metal surfaces, adhere to metalic surfaces and form a protective barrier against the electrolytes.

2.2.3 CARBON CRITERIA. Intergranular corrosion could be lessened by limiting the amount of carbon in the steel or by adding a stabilizing element such as titanium, columbium, or tantalum. These elements have a higher affinity for carbon than does chromium and their carbides and are, therefore, preferentially precipitated. However, these stabilizing elements do not prevent corrosion under all conditions. For example, in a carburizing environment, the carbon content of the steel may be raised beyond the capability of the stabilizer. In this event, the carburized surface would be subject to the same chromium carbide precipitation as unstablized steel. Also, in the case of Centaur tanks, this method would reduce the strength below an acceptable level.

SECTION III

CORROSION PROBLEM DEFINITION

3.1 CENTAUR TANK CONSTRUCTION/CORROSION LOCATION

3.1.1 ASSEMBLY. The Centaur tank assembly is a cylindrical pressure-stabilized monocoque structure with a conicoelliptical forward bulkhead and an elliptical aft bulkhead. The structure is separated into two propellant tanks by a double walled intermediate bulkhead which physically separates and thermally isolates the propellants. The tank is constructed of stainless steel sheets of varying thickness, resistance welded to form the assembly. Figure 3-1 is an illustration of the tank assembly showing the various components, the materials used, and the approximate number of spotwelds in each general area.

During the development of the Centaur tank, several configurations evolved. Table 3-1 lists the major differences between the A, B, C, and D type tanks. Some typical weld configurations on the operational type tanks (Series D) are shown for the forward bulkhead, constant skin sections, and the aft bulkhead in Figures 3-2 through 3-4, respectively.

3.1.2 CORROSION LOCATION. The aft bulkheads appear to show the greatest amount of corrosion. This is attributed to the aft bulkhead possessing more doublers than the forward bulkhead and, consequently, more spotwelds and more area for collection of corrodents. The location of the spots affected by corrosion are shown in Appendix B.

3.2 EXTENT AND GROWTH OF CORROSION

3.2.1 MEASUREMENT. The corrosion on Centaur tanks affected a small percentage of the total spotwelds. The maximum amount of corrosion on any Centaur flight tank was 1.25 percent of all spotwelds examined with most tanks showing corrosion in less than 1 percent. This percentage was somewhat higher on those X-rays made during the tank monitoring program since limited samples were inspected and these samples were quite often areas of heaviest corrosion. The extent and growth of this corrosion is shown in Appendix C.

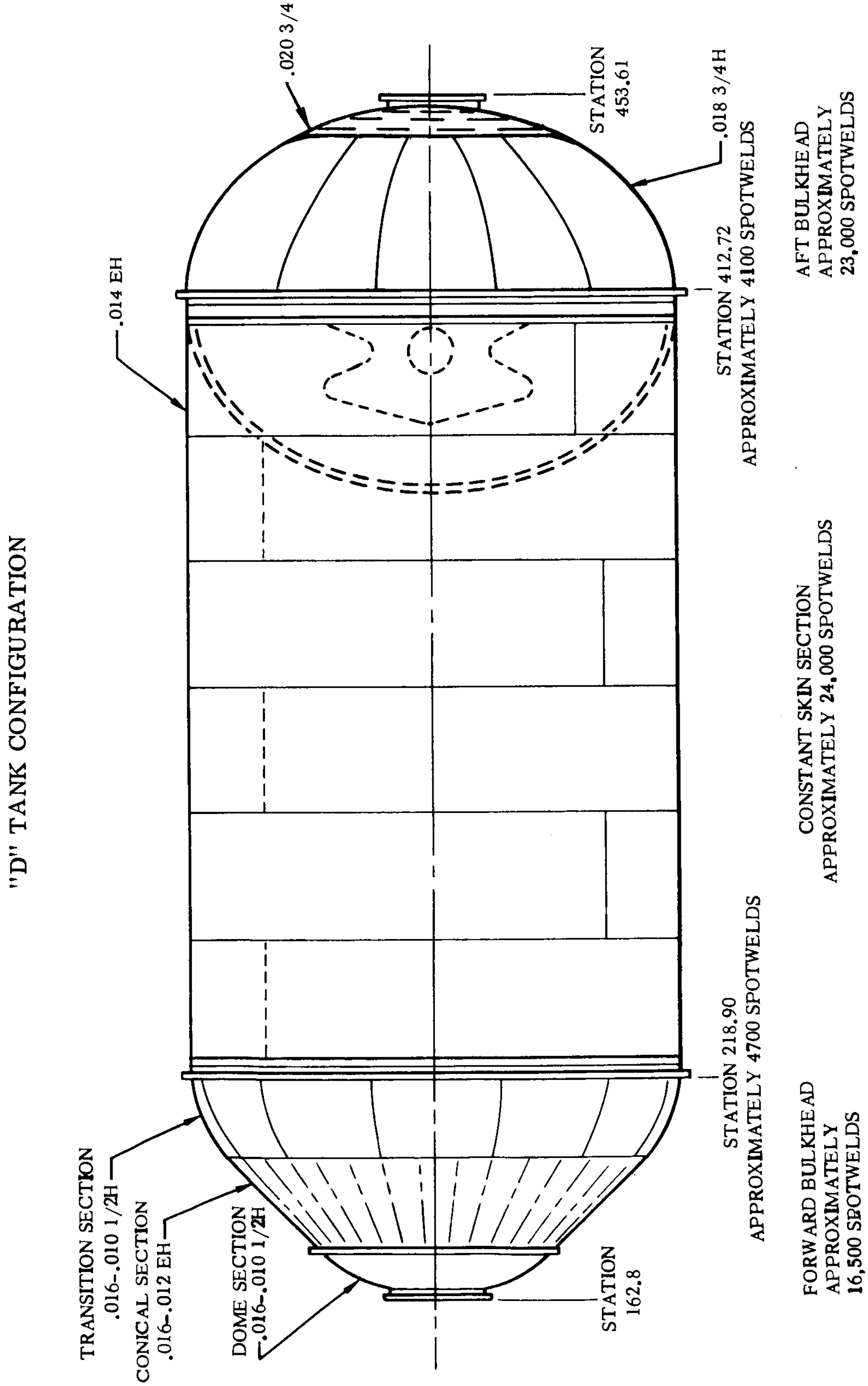


Figure 3-1. D Tank Configuration

TABLE 3-1. BASIC TANK CONFIGURATIONS DIFFERENCES

Item	"A" Tank AC-1	"B" Tank AC-2	"C" Tank AC-3, 4, 5	"D" Tank AC-6 & On
Fwd Bulkhead	1. Fwd gores 0.010 in. thick 2. Conical skins 0.011 in. thick 3. Aft gores 0.012 in. thick	1. Fwd gores 0.016 in. thick 2. Conical skins 0.016 in. thick 3. Aft gores 0.018 in. thick	Same as "B" tank 4. Surveyor type bulkhead	1. Fwd gores 0.016 in. thick with chem milling to 0.010 in. 2. Conical skins 0.016 in. thick with chem milling to 0.012 in. 3. Aft skins 0.016 in. thick with chem milling to 0.010 in.
Constant Skin Section	1. Aft cylindrical section 0.011 in. 2. 5 fwd cylindrical skin sections 0.010 in.	1. All cylindrical skin sections 0.016 in. thick	Same as "B" tank	1. All cylindrical skin sections 0.014 in. thick
Aft Bulkhead	Main skin .022 in. thick	Main skin .020 in. thick	1. Complete aft bulkhead .020 in. 3/4H	1. Main skin 0.018 in. 3/4H

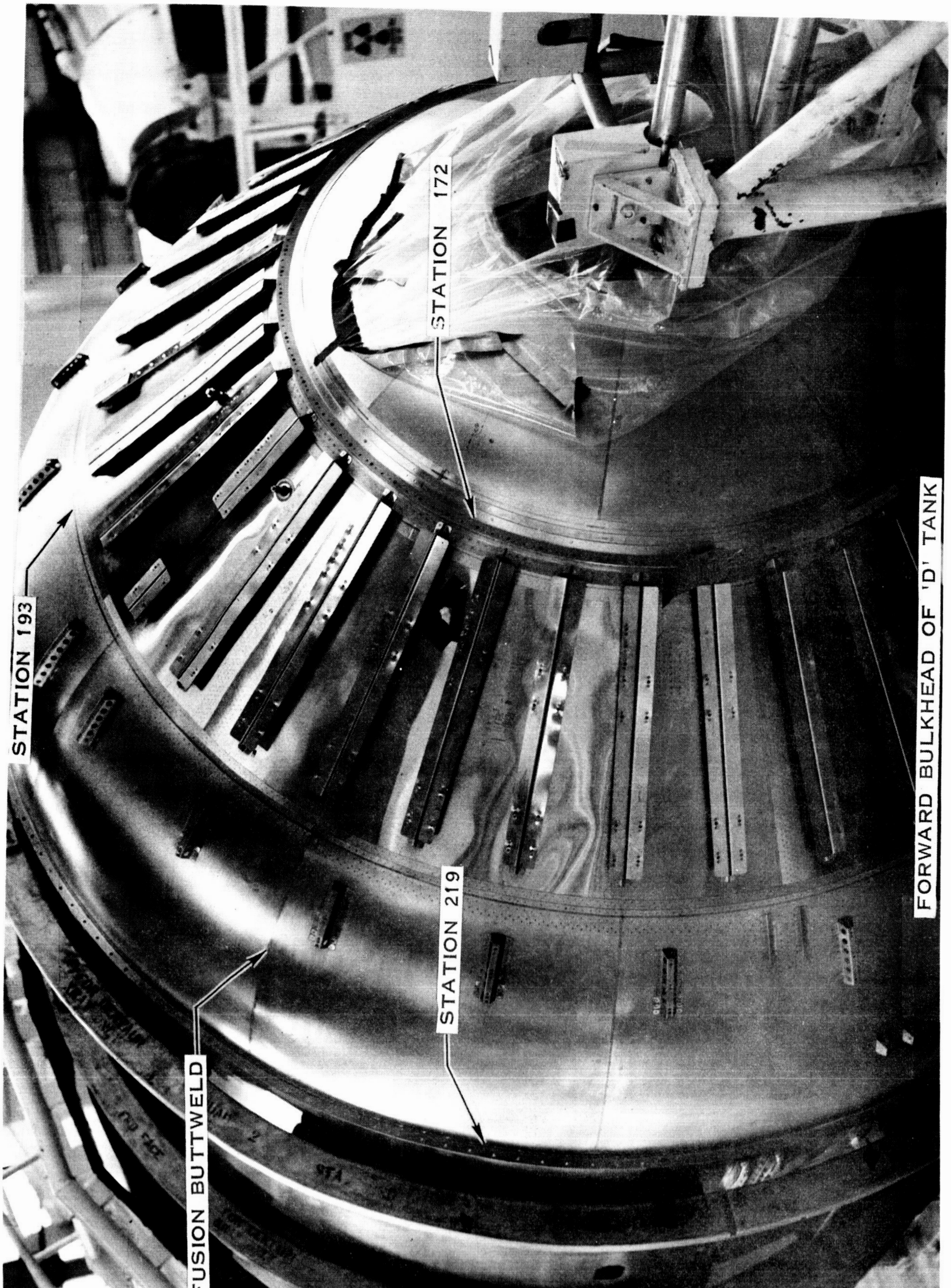


Figure 3-2. Forward Bulkhead

CONSTANT SKIN SECTION OF 'D' TANK

Figure 3-3. Constant Skin Sections

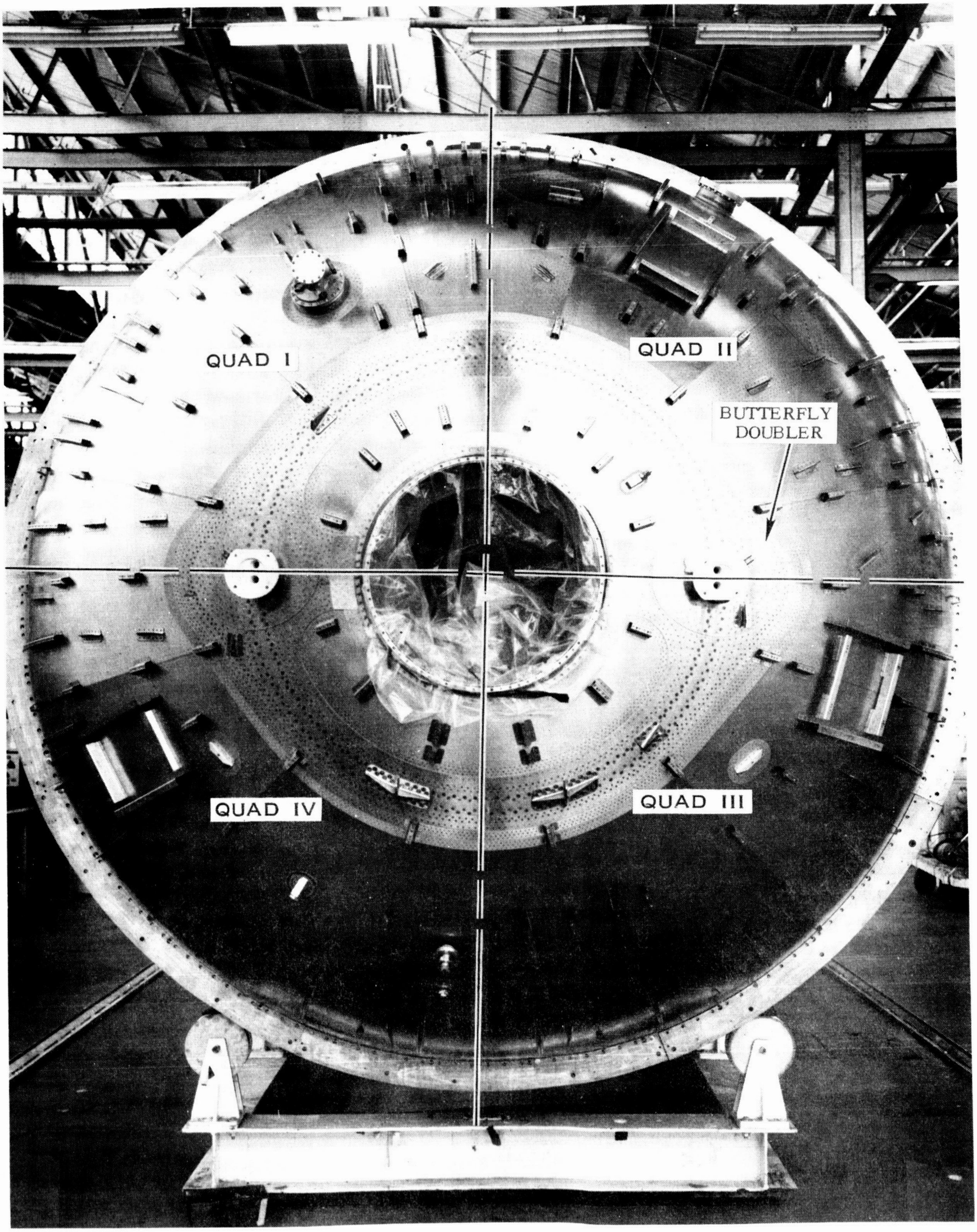


Figure 3-4. Aft Bulkhead

Charts showing crack growth as a function of time are included in Appendix D. The data for these charts were collected by identifying each crack noted on the X-ray and measuring the length. The same cracks were then measured again on subsequent X-rays. This type of examination generally showed that the cracks seldom grew in length.

3.3 POSSIBLE CAUSES OF TANK CORROSION

3.3.1 PROCESSING FLUIDS. Various fluids used in the manufacture of Centaur tanks were suspected of causing corrosion. These fluids were evaluated. A list of processing chemicals evaluated for corrosiveness is shown in Table 3-2. The results of screening tests for these chemicals is shown in Table 3-3.

Metal marking fluids (electrochemical electrolytes) 2611A, 260A, and E. No.1 were very corrosive to stainless steel, while Electrolyte B10 was not corrosive to stainless steel. This was determined by application of these electrolytes to spot-welded panel specimens, as illustrated in Figure 3-5, and rating the resultant corrosion. See Table 3-4. Further testing was done by applying corrodents and maintaining a set of specimens with a stress of 20 ksi and rating resultant corrosion. See Table 3-5.

As shown in Tables 3-4 and 3-5 the cleaning solvents generally were not corrosive to spotwelds; however, certain solvents containing acids, such as TEC 901, were mildly corrosive. Of various other processing chemicals tested, none were significantly corrosive to stainless steel spotwelds as evidenced in Tables 3-4 and 3-5.

Based on these tests only processing chemicals which are not corrosive to stainless steel spotweld, should be used in tank fabrication. They are Electrolyte B10 for marking fluid and TEC 902 and trichlorethylene for solvents.

3.3.2 CHLORIDES. Due to the proximity of the GD/C tank manufacturing plant to the ocean, chlorides, in the form of salt air, may settle on the tanks during storage or between manufacturing processes. When tanks are wiped down with cleaning solutions, chlorides go into solution and may be drawn into faying surfaces by capillary action.

A test to determine the corrosiveness of solvents TEC 901 and TEC 902 combined with salt was conducted by exposing 16 spotwelded stainless steel panels with various corrodents injected into the faying surfaces for three months. Eight samples were exposed at a laboratory environment while eight were exposed at a salt air environment at the Scripps Institute of Oceanography, La Jolla, California. Table 3-6 shows that all samples subjected to salt whether by injection into the faying surfaces or exposed to salt air environment, showed visual evidence of corrosion. Only those exposed to the salt air actually showed corrosion in the spotweld nuggets on X-ray inspection. (For details see Reference 5)

TABLE 3-2. LIST OF PROCESSING CHEMICALS EVALUATED

	Function	Manufacturer	Material Spec.
Electrochemical Etch Electrolytes			
260A	Marking	The Lectroetch Co.	0-00472-003
2611A	Marking	The Lectroetch Co.	0-00472-004
B10	Marking	Monode Marking Co.	0-00472-003
B10A (B10 + 2% Sodium Nitrite)	Marking	GD/C	———
C10	Marking	Monode Marking Co.	0-00472-004
E No. 1	Marking	Electro-Chem Etch, Inc.	0-00472-003
F10	Marking	Monode Marking Co.	———
MSC1	Marking	Marking Methods	0-00472-004
T10	Marking	Monode Marking Co.	———
Cleaning Solvents			
Acetone	Cleaning	Commercial	0-A-51
Freon TF	Cleaning	Du Pont	0-79054-001
Oxylene	Cleaning	John B. Moore Co.	0-00639-001
Tec 901	Cleaning	Tec. Chem. Co.	0-00126-001
Tec 902	Cleaning	Tec. Chem. Co.	0-00126-002
Tec 903	Cleaning	Tec. Chem. Co.	0-00126-003
Trichloroethylene	Cleaning	Commercial	MILT-27602
Miscellaneous Processing Chemicals			
Abrasive Material Pumice Grade FF	Polishing	Commerical	SS-P-821
Brown Line Paper	Packaging	Commerical	———
Bubble Fluid/Leak Detection	Leak Detecting	T. O. Bateman	0-73030-001
Cee Bee MX 8	Cleaning	Cee Bee Chemical	0-79048-001
Coolant from Welder (Internal)	Cooling	———	———
Deionized Water	Cleaning	Commerical	0-73020
Drawing Compound	Forming	Kerns Pacific Corp.	0-00577-001
Dykem	Marking	Dykem Corp.	———
Dye Penetrant	Inspection	Magnaflux Corp.	———

TABLE 3-3. PROCESSING CHEM

Material	Test Sample (Note 1)	Corrosive Action	Sp. Resistance - OHMS - CM	(pH)	
2611A	S	Yes	—	2.7	Calciun
260A	S	Yes	—	1.8	Sodium
E. NO. 1	S	No	—	6.9	Sodium
B10	S	Yes	—	7.4	Sodium
Acetone	S	No	680. $\cdot 10^3$	6.2	
Oxylene	W	No	1950.	7.1	
Tec 901	S	Yes	4.	3.0	
Tec 902	S	Yes	12.	5.2	
Trichloroethylene	W	No	4450.	8.6	
Abrasive Material	W	No	13.	6.2	
Brown Line Paper	W	No	36.5	6.5	
Bubble Fluid/Leak Detection	S	Yes	3.	7.4	
Cee Bee MX 8	W	Yes	0.06	11.4	
Coolant from Welder (Internal)	S	No	0.3	7.9	
Deionized Water	S	Yes	78.	6.6	
Drawing Compound	W	No	0.4	8.7	
Dykem	S	No	1.4	5.4	
Dye Penetrant	S	Yes	140.	5.1	
Dye Penetrant Developer	S	No	268.	8.0	
Dye Penetrant Remover	W	No	1.3	9.3	
Electrochem Etch Neutralizer	S	No	1.3	8.8	
Electroetch Cleaner No. 2	S	No	0.1	11.6	
Green Tape	W	No	310.	6.1	
Paper	W	No	66.	6.4	
Stencil Paper	W	No	25.	5.7	
Rag + Tec 901 + Marking Ink	W	Yes	2.5	3.1	
Tank Wash Sol'n (Cee Bee/D. I. H_2O)	S	No	0.09	11.0	
Water from Welder	S	No	0.9	8.3	
Water Soluble Coolant Oil	S	No	0.3	6.8	
WD - 40.	W	No		5.1	

NOTE: 1. S = Test Sample as received.
2. W = Test Sample - Extract using Equal Volume of Water
3. — Denotes that test was not performed.

TABLE 3-2. LIST OF PROCESSING CHEMICALS EVALUATED (CONTINUED)

	Function	Manufacturer	Material Spec.
Miscellaneous Processing Chemicals (Cont.)			
Dye Penetrant Developer	Inspection	Magnaflux Corp.	———
Dye Penetrant Remover	Inspection	Magnaflux Corp.	———
Electrochem Etch Neutralizer	Cleaning	Electrochem Etch, Inc.	
Electroetch Cleaner No. 2	Cleaning	The Lectroetch Co.	
Green Tape	Tooling	Commerical	0-00234-002
Paper, Brown Kraft	Packaging	Commerical	UUP-268
Stencil Paper L3	Marking	The Lectroetch Co.	———
Rag + Tec 901 + Marking Ink	Cleaning	———	———
Tank Wash Solution (Cee Bee/D. I. Water)	Cleaning	———	———
VPI 220	Corrosion Preventative	Shell Chemical Co.	
Water from Welder	Cooling	———	———
Water Soluble Coolant Oil	Cooling	Mobile Oil Co.	0-00676-001
WD 40	Corrosion Preventative	Rocket Chemical	0-00019-001
Zyglo Developer	Inspection	Magnaflux Corp.	

ICALS - SCREENING TESTS

Chemistry					
Cations		Anions			
Major	Minor	Sulphate	Chloride	Nitrate	Phosphate
; Cobalt	Sodium; Nickel; Magnesium	No	Yes	—	—
Magnesium	Calcium; Copper; Silver	No	Yes	—	—
Cobalt	Nickel; Calcium; Copper Silicon; Magnesium	No	Yes	—	—
; Calcium	Copper; Magnesium	—	Yes	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	Yes	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	No	—	—	Yes
—	—	—	Yes	—	—
—	—	—	—	—	—
—	—	No	No	No	No
—	—	No	No	No	No
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	No	—	—
—	—	No	No	—	—
—	—	No	Yes	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—

3-10-2

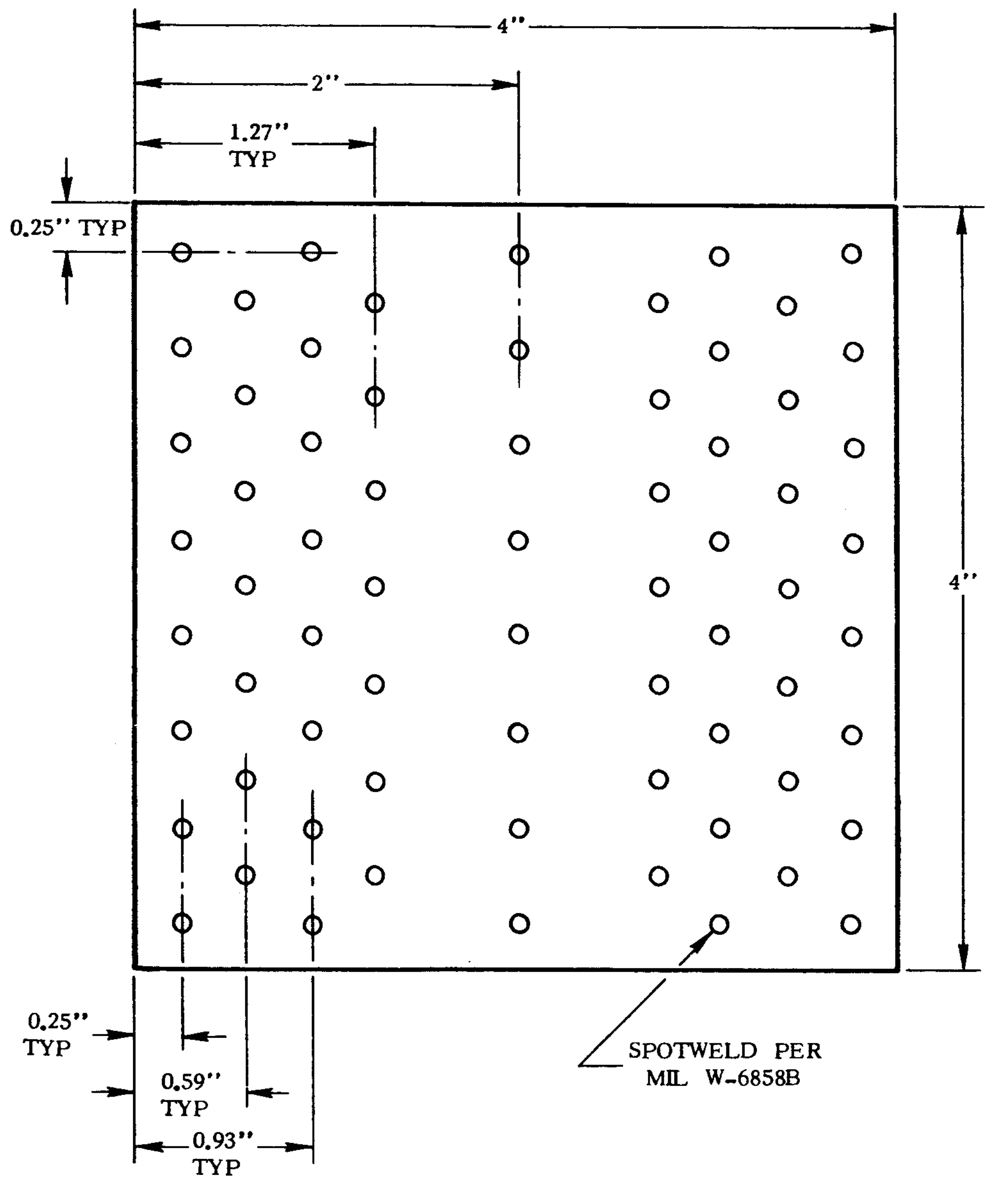
TABLE 3-4. RESULTS OF CORROSION EVALUATION TESTS - SPOTWELDED

Radiographic Analyses - (Total C

	(1964) Start Date		Days From St																							
	Month	Day	7	11	12	14	15	17	18	20	25	28	32	34	35	36	37	38	39	40	42	44	49	51	53	55
	7	29																				6		6		
	7	29																				18		18		
	7	29																				12		16		
	7	29																						0		
	7	29																						0		
	7	29																						0		
	8	7		5						3		4			4						2		1			
	8	7		7						16		19			19						28		34			
	9	16						44												47						48
	9	16						48												48						49
	9	16						33												37						45
	9	16																								44
	9	16																								36
	9	16																								27
	9	16																								23
	10							0					0												0	
	10	9						9					20												33	
	10	9						16					20												31	
	10	9						0					0												3	
	10	9						0					0												0	
	10	9						0					5												5	
	10	8									0															
	10	8									2															
	10	8									7															
	4(65)	7					0																			
	4(65)	7					0																			
Note 2	10	23							14											14						
Note 2	10	23							22											27						
	12	7					22									36										
	12	7					2									19										
	12	7					0									16										
	12	7					0									0										
	12	7					0									1										
	12	7					5									19										

3-12-2

Specimen No.	Corrodent	Remarks
ELECTROCHEMICAL ETCH ELECTROLYTES		
1*	2611A	Wiped with Lectroetch Cleaner No. 2
2*	2611A	
3*	2611A	
10		
11		
12		
19	B10	
20*	260A	
51	2611A	See Note 1
52	2611A	See Note 1
53	2611A	See Note 1
54	2611A	See Note 1
55	2611A	See Note 1
56	2611A	See Note 1
57	2611A	See Note 1
70	E No. 1	Corrodent wiped on
71	E No. 1	
72	E No. 1	Corrodent sprayed on heavily
73	B10	
74	B10	
75	B10	Corrodent sprayed on heavily
119	2611A	Corrodent application light (Note 3)
120	2611A	Corrodent application medium (Note 3)
121	2611A	Corrodent sprayed on heavily (Note 3)
152	B10	Corrodent added after spotwelding
165	B10A	Corrodent added after spotwelding
167	TEC 901 (90%)/2611A (10%)	Corrodent added after spotwelding; 4ft × 6in.
168	TEC 901 (90%)/E No. 1 (10%)	Corrodent added after spotwelding; 4ft × 6in.
178	2611A	
179	MSC 1	
180	MSC 1	
181	B10	
182	B10	
183	E No. 1	



Test sample two sheets spot-welded together 68 spotwelds per sample.

Figure 3-5. Spotweld Corrosion Test Panel Specimen

) PANELS

Corrosion Pits and Cracks) (68 spotwelds per specimen)

art Date

58	59	68	80	83	89	92	95	96	97	107	116	158	159	163	189	248	257	279	289	311	328
8		10			10																
20		19			20																
16		18			16																
0		0			0																0
0		0			0																0
0		0			0																0
	1		1								1	2								6	
	35		38								38	40			41						
																		64			
																		64			
																		59			
							0									4					
							44									53					
							37									49					
							3									1					
							0									1					
							5									0					
		0																			
		0																			
										46					45	See Note 6					
										35					43						
										26					47						
										0					0						
										1					2						
										29					38						

3-12-3

ED PANELS (Continued)

yses - (Total Corrosion Pits and Cracks)

Days From Start Date

1	53	55	58	59	68	80	83	89	92	95	96	97	107	116	158	159	163	189	248	257	279	289	311	328
																				0				
																				0				
																				0				
																				0				
																				0				
																				0				
																				0				
																				0				
																				0				
											0						0							
									0							0								
											0													
																		2						
																		2						
																		0						
																		0						
							3				0													
																						1		
																						8		
									0															
									0															
							3																	
							2																	
							7																	
							3																	
							6	See Note 6																
							5																	
							2																	

Specimen No.	Corrodent	Remarks
WELDING SUSCEPTIBILITY SPECIMENS (Continued)		
175	2611A (Light)	Normal Setup - Round
		Normal Setup - Irregular
		Low Penetration - 22%
		High Penetration - 75%
		Normal setup - Add Quench & Temper
		Long Weld Time - 10 cycles
		Expulsion

NOTE:
1. Specimens 51 - 57 were prepared from 0.020 inch thick CRES.
2. Specimens 167 - 168 were exposed out-of-doors.
3. Results listed for 119 - 121 are inclusions.
4. Specimens 149, 150, 151, 152, and 165 (4 in. × 6 in.) had their spotwelding. The corrodents were applied twice weekly for six were exposed out-of-doors.
5. Specimens 5 and 5A prepared by Centaur Reliability Control. Specimen 5 was exposed to LN_2 and Cee Bee detergent wash. Specimens were exposed indoors.
6. Minor discrepancies in total number of defects due to operator d interpretation.
7. Samples marked by asterisk (*) were sectioned for further study

TABLE 3-4. RESULTS OF CORROSION EVALUATION TESTS - SPOTWELD

Radiographic Anal

(1964) Start Date																							
Month	Day	7	11	12	14	15	17	18	20	25	28	32	34	35	36	37	38	39	40	42	44	49	5
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	14			0										0									
10	23							0									0						
10	27				0								0										
10	23							0									0						
12	7					0																	
12	7					0																	
12	7					0																	
12	7					0																	
10	23							0									0					3	
7	27																						
7	27																						
10	27					0							0										
10	27					0							0										
11	24	2									2											3	
		1									1											1	
		1									6											6	
		1									3											5	
		1									4											4	
		4									6											7	
		2									3											4	

TABLE 3-4. RESULTS OF CORROSION EVALUATION TESTS - SPOTWELDED PAN

			Radiographic Analyses																						
			Days																						
	Month	Day	7	11	12	14	15	17	18	20	25	28	32	34	35	36	37	38	39	40	42	44	49	51	53
	11	24	0									0											0		
			0									0											0		
			0									0											0		
			0									0											0		
			0									0											0		
			0									2											2		
			0									0											0		

corrodents added after
weeks. The specimens

ifferences in X-ray

(See Table 5-2).

Specimen No.	Corrodent	Remarks
CLEANING SOLVENTS		
76	Freon TF	
77	Freon TF	
78	Freon TF	
79	TEC 902	
80	TEC 902	
81	TEC 902	
82	Tric	
83	Tric	
84	Tric	
152	Trichloroethylene	See Note 4
165	Oxylene	See Note 4
166	TEC 901	
201	Trichloroethylene	
202	Freon TF	
203	TEC 901	
204	TEC 901	
MISCELLANEOUS PROCESSING CHEMICALS		
151	Red X Bubble Fluid	See Note 4
5	Dykem	See Note 5
5A	Dykem	See Note 5
149	TEC 903 + MMI	See Note 4 MMI ≡ Mill Marking Ink
150	TEC 902 + MMI	See Note 4 MMI ≡ Mill Marking Ink
WELDING SUSCEPTIBILITY SPECIMENS		
174 *	2611A (Heavy)	Normal Setup - Round
		Normal Setup - Irregular
		Low Penetration - 22%
		High Penetration - 75%
		Normal Setup - Add Quench & Temper
		Long Weld Time - 10 cycles
		Expulsion

ːLS (Continued)

– (Total Corrosion Pits and Cracks)

ː From Start Date

55	58	59	68	80	83	89	92	95	96	97	107	116	158	159	163	189	248	257	279	289	311	328
					0																	
					0																	
					0																	
					0																	
					0																	
					2																	
					0																	

CRACKING TEST - 20 KSI

nt ion e	Start Date				Corrodent Application Stopped				Test Terminated				Radiographic Analyses Days from Start Date (Total Corrosion Pits and Cracks)											
s/Week)													I								II			
II	I		II		I		II		I		II		14	22	44	52	66	84	141		11	13	68	70
	9	8			11	13			1	27				17	49		63		64					
	9	8			10	27			10	28				28	55									
	4	28											0											
	4	28											0											
	9	8			11	13			1	27				34	49		56		64					
	4	28											0											
	4	28											0											
	9	8			11	13			1	27				29	58		61		64					
	11	2			12	1			1	27			3		14			18						
	4	28											0											
	4	28											0											
	4	28											0											
	4	28											0											
	9	8			11	13			11	13				1	4		4							
	9	8			11	13			1	27				6	12		19		19					
	4	28											0											
	4	28											0											
2	9	8	11	20			12	1	11	13	1	27		0	0		0				0		0	
	9	8			11	13			11	13				0	0		0							
2	9	8	11	18	11	13	12	1	11	13	1	27		0	0		0					0		1
2	9	8	11	18	11	13	12	1	11	13	1	27		0	0		0					0		0
	9	8			11	13					1	27		0	0		0		0					
	4	28											0											
	4	28											0											
	9	8							11	13				0	0		0	0	0					
	9	8			11	13			1	27				0	0		3		3					
	4	28											0											
	4	28											0											
	9	8			11	13			1	27				0	9		9		8					
	4	28											0											
	4	28											0											
	9	8							1	27				0	0		0		0					
	9	8			11	13			1	27				46	52		52		52					
	3	3			3	17										0			0					
	4	13			4	27							0					0						

y and after two weeks.

2. Other specimens prepared from 301 CRES 0.010 in. XH

TABLE 3-5. STRESS CORROSIO

Specimen No.		Corrodent I	Corrodent II	Corrod Applica Schedu (No. of Time
I	II			I
A	*	2611A		Initial
B		2611A		2
701		2611A		Note 1
702		2611A		Note 1
C	*	260A		2
718		260A		Note 1
719		260A		Note 1
D		E. No. 1 (Initial 260A)		2
S		E. No. 1		2
720		E. No. 1		Note 1
721		E. No. 1		Note 1
722		B10		Note 1
723		B10		Note 1
G		Tec 901 + Mill Marking Ink		Initial
H	*	Tec 901 + Mill Marking Ink		2
726		Tec 901 + Mill Marking Ink		Note 1
727		Tec 901 + Mill Marking Ink		Note 1
1	W	Tec 901/CB MX 8-D. I. H_2O	Tech 902 + Mill Marking Ink	Initial
J		Tec 901/CB MX 8-D. I. H_2O		2
M	U	Tec 901	Trichloroethylene	Initial
N	V	Tec 901	Tric. + Mill Marking Ink	2
O		Tec 902		2
728		Tec 902		Note 1
729		Tec 902		Note 1
732		Trichloroethylene		Note 1
734		Oxylene		Note 1
E		Red X Bubble Fluid		Initial
F		Red X Bubble Fluid		2
724		Red X Bubble Fluid		Note 1
725		Red X Bubble Fluid		Note 1
P	*	Dykem Ink		2
730		Dykem Ink		Note 1
731		Dykem Ink		Note 1
733		Monode APC Cleaner		Note 1
K		Control (Not Cleaned)		
L	*	Magnesium Chloride (42 Wt %)		2
7		B10		2
8		B10A		2

NOTE: 1. 7XX. Specimens prepared from 301 CRES 0.018 in. 3/4 H. corrodent added initiall

3. *Indicates specimens which were sectioned. See Table 5-2 for results

TABLE 3-6. SUMMARY OF CORROSION

Specimen Number	Faying Surface Contaminant	Location of Exposure (3 Months)	Results of Examination	
			Visual-Exterior	X-Ray-Spotwelds
1	TEC 901	Lab	No corrosion	No corrosion indicated
2	TEC 902	Lab	No corrosion	No corrosion indicated
3	Trichloroethylene	Lab	No corrosion	No corrosion indicated
4	20% NaC1 + TEC 901	Lab	Discoloration and some rust	No corrosion indicated
5	20% NaC1 + TEC 902	Lab	Discoloration and some rust around spotwelds	No corrosion indicated
6	20% NaC1 + Trichloro.	Lab	Some discoloration and some rust around spot-welds	No corrosion indicated
7	20% NaC1	Lab	Rust spots around spot-welds	No corrosion indicated
8	Control (not exposed)	Lab	No corrosion	No corrosion indicated
9	TEC 901	Scripps	Rust in faying surface	Pitting corrosion around two of the spotweld nuggets
10	TEC 902	Scripps	Rust in faying surface	Very dark area around middle spot
11	Trichloroethylene	Scripps	Rust in faying surface	Pitting corrosion indicated around spotweld nuggets
12	20% NaC1 + TEC 901	Scripps	Rust in faying surface plus staining	Pitting around spots indicated
13	20% NaC1 + TEC 902	Scripps	Rust in faying surface	Pitting around spots indicated
14	20% NaC1 + Trichloro	Scripps	Rust in faying surface	Pitting around two spots ind.
15	20% NaC1 + solution	Scripps	Rust in faying surface	Pitting corrosion around spots indicated
16	Control	Scripps	Rust in faying surface	Pitting corrosion around spot-weld nuggets

3.3.3 STRETCH FORMING. Tests were made to determine if corrosive substances were transferred to skins by stretch forming machines or by water used for cooling during welding. The results were negative.

3.3.4 CHEMICAL PROCESSING FLUIDS. Checking for corrosive substances deposited or collected on component tank skins following surface treatment such as chem-milling or passivation proved negative. All chem-milled parts are passivated following chemical processing. Following passivation, parts are thoroughly rinsed in water and dried. As a result, there have been no indications that either passivation or chem-milling processes have contributed to tank corrosion.

3.3.5 WELDING TECHNIQUES. Since the corrosion in this program has been detected primarily around spotwelds in faying surfaces, and since local stress as well as the corrodents appear to be involved, tests were performed by varying welding parameters to vary localized stresses. Light and heavy applications of 2611A were used as the corrosion inducing media for these tests.

Eight identical spotwelds were made for each of the weld schedules and corrodent concentrations. The following welding parameters were evaluated:

a. Normal set up - round spots.
b. Normal set up - irregular spots.
c. Low penetration - 22%.
d. High penetration - 75%.
e. Normal set up plus quench and temper.
f. Long weld time - 10 cycles (Ten times longer than normal weld time)
g. Expulsion.

After the specimens were prepared, the specimens were stored at room temperature at 100 percent relative humidity. The specimens were radiographed periodically to detect corrosion. The results are presented in Table 3-4. After three weeks, only one corrosion crack and one corrosion pit developed in the specimen with light application of 2611A. These were among the "long weld time" spotwelds. Corrosion pits or cracks developed among some of the spots of all the welding conditions on the panel when the corrodent was applied in a heavy manner. The data appears too meager to draw firm conclusions about the effect of welding parameters on corrosion susceptibility.

SECTION IV

PREVENTIVE MEASURES

4.1 CORROSION INHIBITORS

4.1.1 INTRODUCTION. A corrosive solution or electrolyte must be present for corrosion to develop in the faying surfaces of spot-welded type 301 CRES. The most corrosive materials are acids and acid salts. Alkalies or alkaline salts seem to be relatively non-corrosive in this situation. Methods of neutralizing corrodents and inhibiting corrosion were investigated.

4.1.2 AMMONIA. Since ammonia gas is alkaline in nature, penetrating, and relatively inert to a large number of materials, tests were conducted to determine the feasibility of its use as a corrosion inhibitor.

Specimens were prepared from 301 CRES, 3/4 H, 4 inches × 4 inches × 0.020 inches and 4 inches × 4 inches × 0.018 panels. Panels were spot-welded as shown in Figure 3-5. This panel combination was defined as a test specimen. The following preparation procedure was performed.

a. Identify every second panel with a specimen number.

b. Thoroughly clean the panel with cheesecloth soaked in TEC 901 solvent.

c. Wash the panel by scrubbing with tap water and cheesecloth.

d. Wash the panel by scrubbing with de-ionized water and cheesecloth.

e. Dry the panel with cheesecloth.

f. Saturate a piece of cheesecloth with Lectroetch 2611A.

g. Wipe the Lectroetch 2611A onto one side of both panels.

h. Allow to dry.

i. Place the two panels into a polyethylene bag; Lectroetch sides in. Seal the bag with masking tape.

j. Spot-weld per Figure 3-5.

Figure 4-1 shows the result of maintaining test specimens in an ammonia environment, then removing specimens into 100 percent relative humidity environment. As Figure 4-1 shows, the ammonia does not give lasting protection once the specimen is removed from the ammonia environment. The three specimens retained in the ammonia environment did not corrode.

Figure 4-2 shows the results of allowing specimens treated with corrodents to corrode and then placing specimens in an ammonia environment. As Figure 4-2 shows, the ammonia inhibitor does not appear to retard corrosion once the corrosion has started.

4.1.2.1 Effect of Ammonia on Tank Material. For screening tests, simple exposure tests were made with 10 percent wet ammonia and 10 percent dry ammonia (-60° F dewpoint) for a group of representative materials. See Table 4-1 for a list of the materials tested and the visual results. A list of materials used in the Centaur vehicle is presented in Table 4-2.

4.1.2.2 Stress Corrosion Test. Under a dry ammonia environment certain Centaur tank structural materials were exposed to 30 percent dry (-60° F dewpoint) ammonia vapor for 49 days while being stressed to 95 percent of yield strength. Unexposed specimens were stressed at the same level for the same length of time as controls. The change in room temperature tensile strength was determined after exposure. See Table 4-3 for results. Test results show no significant deterioration in room temperature mechanical properties due to NH_3 exposure for 49 days for the materials listed.

4.1.2.3 Conclusions. As a result of this investigation, the following was determined:

a. Dry Ammonia as a Corrosion Inhibitor - The tests in this program have shown that ammonia gas, even at 1 percent by volume, is effective in retarding corrosion in corrosion-prone resistance spotwelded stainless steel specimens. However, upon removal of the ammonia, corrosion immediately starts. In order to be effective, the ammonia would have to be present the entire life of the vehicle. Dry ammonia seems to have little effect on most materials on a short term basis. There is a multitude of materials present in the final assembled vehicle which have not been tested on a long term basis. Certain components, such as electrical circuits, transducers, valves, etc., may require basic material tests as well as system tests. Dry ammonia gas is effective as a corrosion inhibitor for faying surface corrosion of resistance spotwelded type 301 CRES when applied initially and continuously.

b. Operational and safety problems appear solvable.

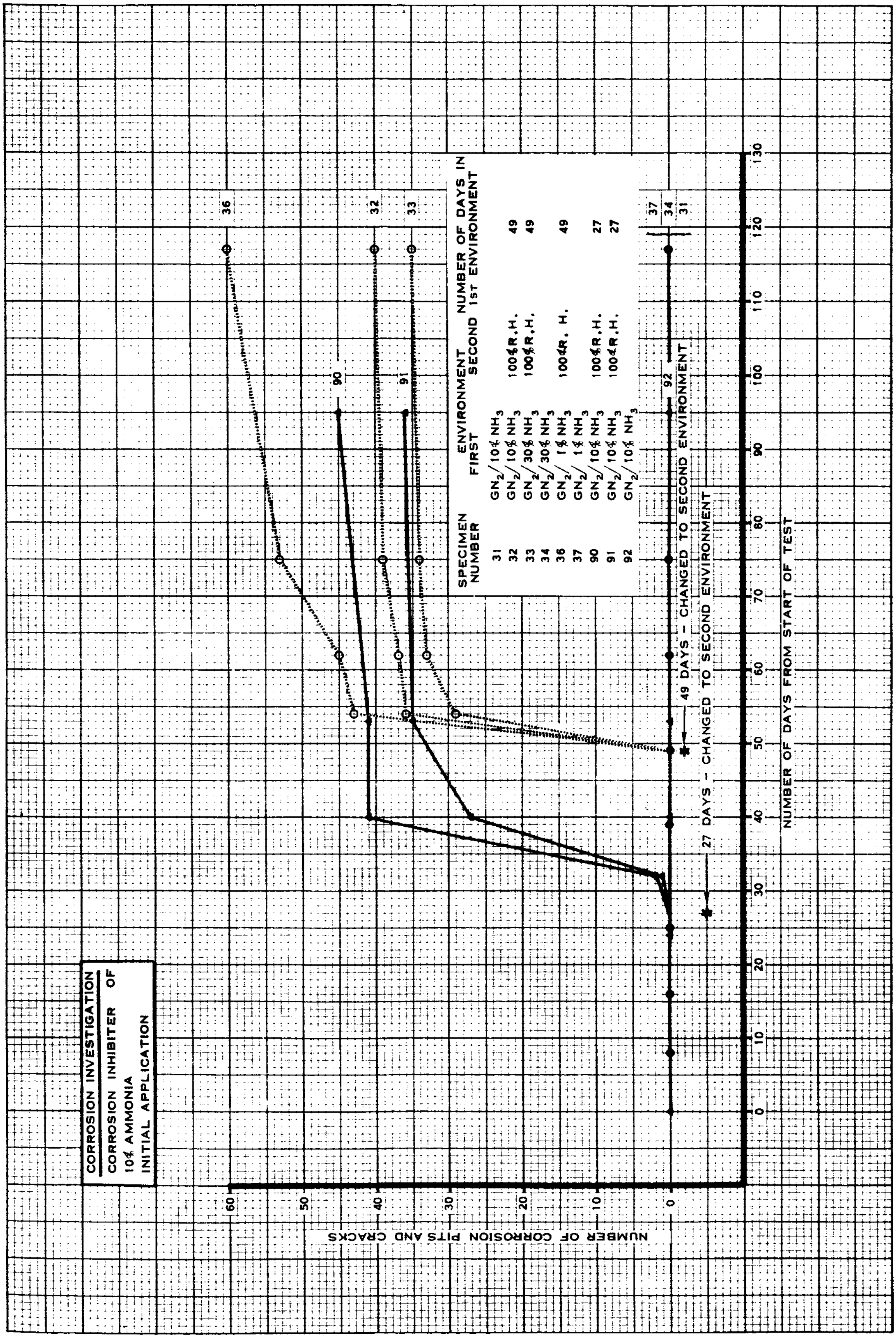


Figure 4-1. Corrosion Inhibitor - Initial Application

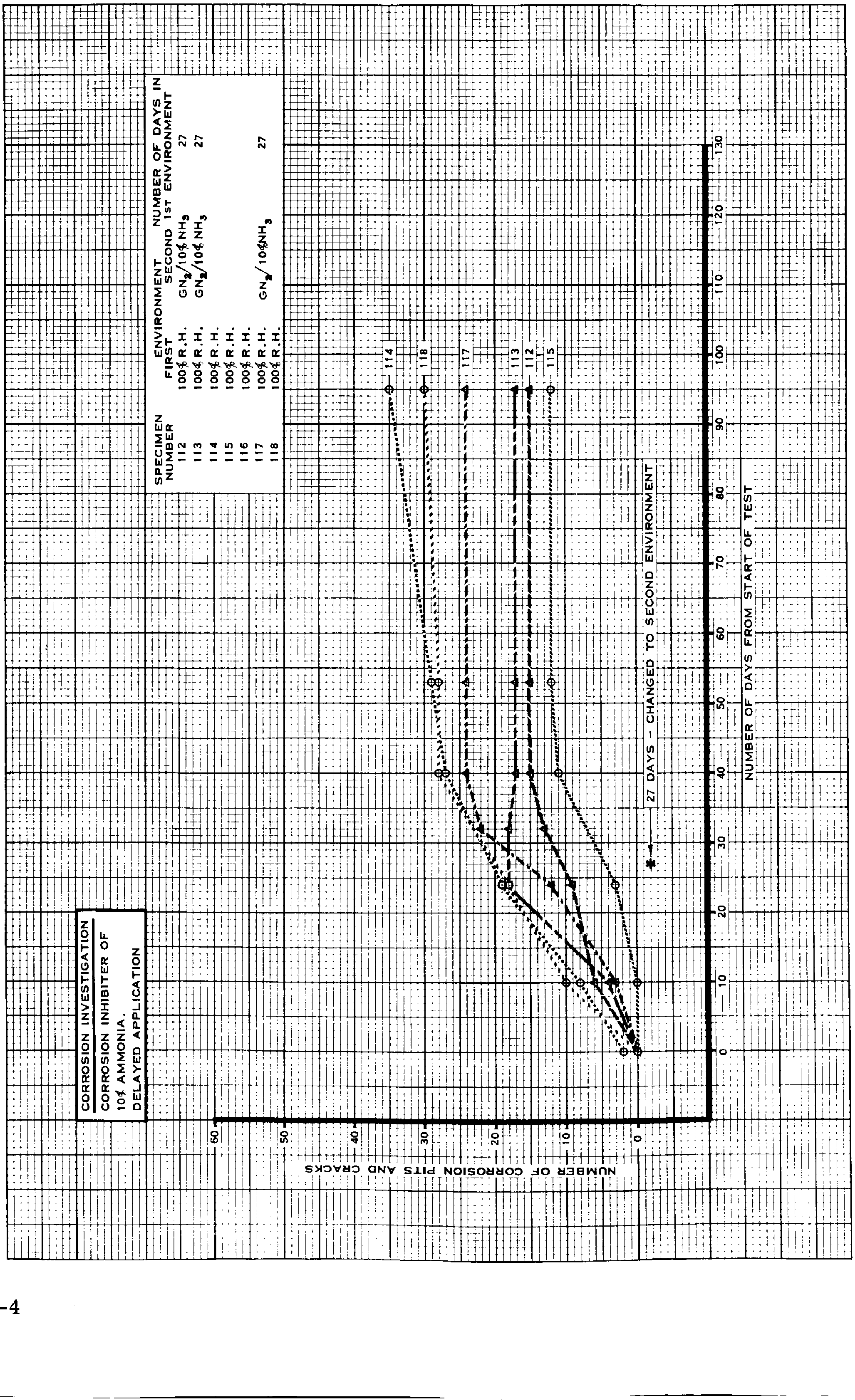


Figure 4-2. Corrosion Inhibitor - Delayed Application

TABLE 4-1. EFFECT OF AMMONIA ON MATERIALS - SCREENING TESTS

Material	Exposure Time	10% NH_3 Wet	10% NH_3 Dry	30% NH_3 Dry
Teflon	6 days	No effect	No effect	
Kel-F	6 days	No effect	No effect	
CRES 301 EH	6 days	No effect	No effect	
Solder (60-40)	6 days	No effect	No effect	
Alum. Alloy (2024, 6061)	6 days	Slight pitting	No effect	
Silver Braze Alloy	6 days	Attacked	No effect	
Gold Plated Brass	6 days	Blue-black corrosion	No effect	
Silver Plated Nut Plate	6 days	No effect	No effect	
Silver Plated Copper Wire	6 days	Attacks copper	No effect	
Copper Foil	6 days	Turned black	No effect	
Soldered Joints (Sn10)	1 day	———	———	No effect

TABLE 4-2. TYPES OF MATERIALS USED IN CENTAUR VEHICLE

300 Series CRES	Beryllium-bronze
Aluminum alloys	Silver Braze
K Monel	Ni Span C
A286 CRES	Pot Metal
Incaloy 805	Tin plated copper wire
Zinc plated aluminum alloy	Teflon
Rene 41 gold plated	Mylar
Platinum wire gold plated	Kel-F
Lead-tin solder (50-50), (90-10)	Polethylene
Copper wire, silver plated	Buna N
Anodized aluminum	Ceramic
Bronze, Cadmium - Nickel plate	Polyurethane foam*
Copper, Cadmium - Nickel plate	Epoxy glue and potting compound*
Brass	
R Monel	

*Sealed in metal with solder

TABLE 4-3. ROOM TEMPERATURE MECHANICAL PROPERTIES AFTER STRESS CORROSION TEST

Material	Size	Environment	Sustained Stress	Fty	Ftu	e
301 EH CRES	.010	NH_3	95% Fty	194,343	205,503	4.5
301 EH CRES	.010	Control	95% Fty	193,344	205,848	6.0
301 1/2H CRES	.020	NH_3	95% Fty	130,503	165,515	28.5
301 1/2H CRES	.020	Control	95% Fty	130,113	165,497	26.5
7075-T6	.025	NH_3	95% Fty	70,236	78,462	10.5
7075-T6	.025	Control	95% Fty	70,534	78,856	10.5
2024-T3	.050	NH_3	95% Fty	44,203	64,830	18.0
2024-T3	.050	Control	95% Fty	43,944	63,361	17.5

Additional details of tests conducted on ammonia as a corrosion inhibitor are given in Reference 4.

4.1.3 VAPOR PHASE INHIBITOR (VPI). Vapor Phase Inhibitor is a powdery substance which sublimes to form a gas. The gas formed by this vaporization contains certain corrosion inhibitors to prevent or arrest corrosion. The feasibility of adding VPI in the vapor state to the Centaur tank was investigated. From the vapor pressure curves of VPI Number 220 it was determined that 0.5 grams of the material would be required to saturate the N_2 gas in the LO_2 tank at STP (Standard Temperature-Pressure). In a simple apparatus where N_2 gas was passed through 1 gram of solid VPI 220 at 8 liters per minute, the following evaporation rates were obtained:

a. 80° F — 0.035 grams/hour

b. 100° F — 0.115 grams/hour

c. 120° F — 0.210 grams/hour

From this data it is obvious that an apparatus could be easily designed to evaporate 0.5 grams of VPI 220 into the tank in a reasonable length of time.

This VPI is also available in paper form. The paper is impregnated with VPI and used to wrap items to be protected from corrosion.

4.1.3.1 Testing. Tests were conducted in order to evaluate the effectiveness of VPI as an inhibitor when applied to Centaur tanks. These tests were conducted on panels fabricated from two 4-inch-square sheets of .018 gage, 3/4 H, 301 CRES. The material was from the same heat and coil as used in the 3D (AC-7) aft bulkhead.

The treatment of the panels consisted at first chemically cleaning and then spraying contaminant on one of the surfaces. The two halves were joined with nine rows of spotwelds. The contaminant treated surfaces were made the faying surface of the specimens. The treated panels were then placed in closed glass dessicant jars containing the various test environments. They were removed periodically and inspected for corrosion by radiography. The results are shown in Table 4-4. As indicated by the results of these tests, VPI was indicated to be an ineffective faying surface corrosion inhibitor.

4.1.4 WD-40 INHIBITOR. This compound is the trade name of an oil base inhibitor which is a water displacement agent. It has a low surface tension and a high affinity for metal surfaces. As a result, WD-40 adheres to metal surfaces forming a protective barrier against corrosion. It has also been shown to be an effective corrosion preventer and arresting agent. However, it is not LO_2 compatible and therefore cannot be used inside the tank.

NOTE

> LO_2 compatibility tests conducted with WD-40 have shown that it is LO_2 compatible in very thin films. These films, however, are so thin that the corrosion inhibiting value would be questionable.

Research is continuing in an effort to find an inhibitor which is LO_2 compatible. Results of this research will be included in the subsequent addendum to this report.

4.2 CORROSION PREVENTIVE MEASURES

4.2.1 INTRODUCTION. The most effective method of eliminating spotweld corrosion is to eliminate the agents necessary for its formation. This can be done by maintaining a clean environment surrounding the tanks and component parts during fabrication. A program to maintain cleanness has been initiated. This program consists of protection of tanks, inspection of tanks, control of all corrosive fluids used in the tank manufacturing process, and passivation of all CRES parts. Each is herein defined more fully.

4.2.1.1 Protective Covers and Wrapping. Centaur sub-assemblies, such as forward, intermediate, insulation and aft bulkheads, cylindrical skins and tanks, are now covered when in storage or between work shifts. Large and small items of cleaned hardware are being packaged in heat sealable, transparent flexible mylar or polyethylene containers. This packaging is being accomplished in contamination-controlled areas.

4.2.1.2 Tank Inspection. One hundred percent inspection of mating surfaces and detailed parts of forward, intermediate, and insulation bulkheads, and constant section skin assemblies, just prior to welding has been implemented. Inspections are made to insure that all surfaces are free of acids, bases, and salts.

TABLE 4-4. VAPOR PHASE INHIBITOR - EVALUATION TESTS

Panel No.	Test Conditions		Test Objectives	Results
	Specimen	Environment		
1	Sample contaminated with an electroetch B10 (suggested for replacement of 2611A) and spot-welded.	Placed in a vessel containing initially VPI 250 and finally VPI 220 and 100% humidity.	To determine if VPI 250 or VPI 220 would inhibit corrosion produced by B10 electroetch.	Other tests show that VPI 250 does not inhibit faying surface corrosion. The lack of any pits or cracks after 7 weeks further confirmed test results from B10 test. It appears that B10 electroetch causes little corrosion.
2	Sample contaminated with 260A electroetch and spot-welded.	Placed in a vessel where 100% humidity and with VPI 250 and VPI 220 powder present.	To determine if VPI would inhibit corrosion produced by 260A electroetch.	Most rapid corrosion occurred. There were 12 pits and 24 cracks produced in 7 weeks of exposure.
3	Sample contaminated with 2611A electroetch, spot-welded, and wrapped in VPI paper.	Exposed to normal laboratory atmosphere.	To determine if VPI paper could prevent corrosion in faying surfaces of joints.	VPI was ineffective in preventing corrosion in faying surfaces. Test discontinued.

TABLE 4-4. VAPOR PHASE INHIBITOR - EVALUATION TESTS (CONTINUED)

Panel No.	Test Conditions		Test Objectives	Results
	Specimen	Environment		
4	Contaminated with 2611A electroetch, two treated surfaces placed together and wrapped in VPI paper	Exposed to normal laboratory atmosphere.	To determine if VPI paper could prevent corrosion in unwelded faying surface.	VPI did penetrate about 1/4 inch around the pheriphery of the specimen. However, lack of adequate penetration was evident. Test discontinued.

4.2.1.3 Corrosive Fluids Control. Cleaning agents used in manufacturing processes have been tested. TEC 901, a general purpose cleaning solvent, which was used on stainless steel and for other cleaning purposes, has been found to be mildly corrosive. This cleaner has been replaced by TEC 902, except for removal of mill marking ink. TEC 901 is basically the same as TEC 902, except that TEC 901 contains fluosilicic acid. The following revisions have been made to GD/C Specifications to control the use of cleaning solvents:

a. Manufacturing Specification Revision Notices have been issued against Manufacturing Specifications 61.11.2, 61.11.3, and 61.11.4 (which specify cleaning and protective coating for Centaur and Atlas exterior surfaces) eliminating the reference to TEC 901 and replacing it by TEC 902.

b. GD/C Engineering Specification 0-79025 (Cleaning Procedure, Stainless Steel, Unpainted, Surfaces, Airborne Equipment) has been revised to include TEC 902 as a cleaning solvent.

c. GD/C Material Standard ESO-00126 (Solvent, Cleaning, General-Purpose), has been revised to specify that TEC 901 solvent cleaner be dyed for indentification purposes. This has been done to facilitate control of the use of TEC 901 as outlined in Manufacturing Specification 60.54.

d. MS 60.54 (Cleaning, Solvent Wipe, Stainless Steel) has incorporated the changes in ESO-00126 and ESO-79025. This change specifically limits the use of TEC 901 cleaner to removal of mill markings on stainless steel. TEC 902 or trichloroethyene solvents are to be used in all other application which require hand wipe cleaning.

For electroetch solutions, instructions specifying locations and conditions for electro-chemical etch identification have been issued. The basic intent of the instructions is to direct production personnel not to place Electroetch markings in areas which will become faying surfaces of welded tank components. Tests have been conducted to determine if a less corrosive electro-chemical marking fluid is available. As a result of screening tests and stress corrosion tests, Electrolyte B-10 manufactured by Monode Corporation has been recommended for marking stainless steel.

4.2.1.4 Passivation. In order to insure the removal of all surface contaminants and provide additional corrosion protection, all gore skins which are not chem-milled and all formed doublers and brackets are being passivated.

To ensure passivation of all heat and corrosion resistant ferrous alloys, except AISI 303, 416, or 430 FM, Quality Planning Control personnel were instructed to verify that passivation is included as a processing requirement on all production planning created to manufacture parts from these heat and corrosion resistant alloys. All non-chem-milled gore skins and all doublers and brackets are now being passivated in accordance with Manufacturing Specification 71.01 (Passivation of CRES Alloys). Chem-milled gore skins are passivated in the chem-milling process.

4.2.1.5 Summary. The effectiveness of these preventative measures is indicated by the low quantity of corrosion found on Tanks 7D, 8D, and 9D, which have been fabricated utilizing improved manufacturing procedures and processing materials. (Appendix B.)

SECTION V

ACCEPTANCE STANDARDS

5.1 RESISTANCE WELDED SPECIMENS

5.1.1 INTRODUCTION. To determine the effects of corrosion on the load carrying capability of resistance welded structures, the following test program has been established:

a. Perform stress corrosion testing on approximately 40 specimens for six months under a continuously applied load of 20 ksi.

b. Corroded and non-correded control specimens shall be subjected to cyclic fatigue loading of 0 to 135 ksi. Other specimens shall be exposed to sustained loading at 135 ksi for 16 hours followed by sustained loading at 160 ksi for 16 hours. These tests shall be conducted at -320°F or -423°F, as applicable.

Testing on the above program was delayed because of difficulties encounted in producing cracks similar to those found in actual tanks. During the tank corrosion test program various corrodents have been applied to 4 inches × 4 inches welded panel specimens in an attempt to reproduce the corrosion found in actual tanks. Although X-ray examinations indicated corrosion cracks at some spotwelds, sectioning of sample welds containing these apparent cracks showed then to be elongated pits. Continuing tests have resulted in producing cracks similar to those found in Centaur tanks by application of Electroetch 260A together with stress application. The stress testing accomplished, and in process, in support of the overall tank prevention program is now defined.

5.1.1.1 Fatigue Tests. Fatigue tests of simulated tank joints were conducted at both -320° F and -423° F. These specimens were cycled from 0 to 135 ksi for 200 cycles, then checked for leaks (a leak is defined as a through crack as identified by using dye penetrant). The simulated LO_2 tank joints (3/4 H material) were then cycled from 0 to 160 ksi until they failed and the simulated LH_2 tank joints (XFH material) were cycled at a stress level of 0 to 135 ksi until they failed. Results of these tests are found in Table 5-1.

5.1.1.2 Stress Corrosion Cracking Tests - 20 ksi. Welded test specimens were tested with various corrodents and subjected to sustained loading at 20 ksi. The corrodents used, the resultant corrosion determined by X-ray examination, and the duration of the tests are shown in Table 3-5. None of these specimens failed under test. Sections were made of the more severely corroded specimens which, upon examination, showed the apparent cracks to be elongated pits as shown in Table 5-2.

TABLE 5-1. FATIGUE TESTS ON SIMULATED TANK JOINTS

Code I. D.	Specimen Matl. & Gage	Specimen Conditions	Test Conditions				Remarks
			Stess KSI	Test Cycles	Cycles To Failure	Test Temp. °F	
E-1	301 3/4 H .020	Corroded	135 160	200	382	-320	No leaks Failed on first row of spot welds
E-2		Corroded	135 160	200	810		No leaks Failed on first row of spot welds
E-3		Corroded	135 160	200	406		No leaks Failed on first row of spot welds
C-1		Uncorroded	135 160	200	397		No leaks Failed on first row of spot welds
C-2	301 3/4 H .020	Uncorroded	135 160	200	406	-320	No leaks Failed on first row of spot welds
C-3	301 XFH .016	Uncorroded	135 135	200	413	-423	No leaks Failed on first row of spot welds
C-4		Uncorroded	135 135	200	440		No leaks Failed on first row of spot welds
E-4		Corroded	135 135	200	371		No leaks Failed on first row of spot welds
E-5		Corroded	135 135	200	393		No leaks Failed on first row of spot welds
E-6	301 XFH .016	Corroded	135 135	200	316	-423	No leaks Failed on first row of spot welds

NOTE: 1. Specimens E-1, E-2, E-3, C-1 and C-2 were cycled 200 times at 135 ksi and leak checked; stress was then increased to 160 KSI for additional cycles as indicated.

2. Specimens C-3, C-4, E-4, E-5 and E-6, were cycled 200 times at 135 ksi and leak checked. Cycling was then continued to failure for a total number of cycles as indicated.

TABLE 5-2. SPECIMENS WHICH WERE SECTIONED TO EXAMINE SPOTWELDS

Code No.	Corrodent	Beginning of Test	Date of Last X-ray to be Evaluated	Duration of Evaluation Period (Days)	Corrosion as Indicated by X-Ray		Number of Spotwelds Examined (By X-Rays)	Results From Sectioning*
					Pits	Cracks		
A	2611A Lectroetch	9/8/64	1/27/65	141	3	61	64	Sections showed only pits and elongated - pits, no cracks
C	260A Lectroetch	9/8/64	1/27/65	141	8	56	64	
H	Tec 901 + Mill marking ink	9/8/64	1/27/65	141	3	16	64	
L	Magnesium Chloride (42% by wt)	9/8/64	1/27/65	141	0	52	52	
P	Dyechem Ink	9/8/64	1/27/65	141	0	8	18	
S	E No. 1 Lectroetch	11/2/64	1/27/64	86	7	11	18	
PNL 1, 2, 3	2611A Lectroetch	7/29/64	10/26/64	89	17	29	204	
PNL 20	260A Lectroetch	8/7/64	10/26/64	80	8	30	68	
PNL 174	2611A Lectroetch	11/24/64	1/12/65	49	12	18	68	

NOTE: 1. Numbered Specimens were corroded at 100% R.H. while stressed to 20 ksi.

2. Lettered Specimens were corroded at outside air environment under no load.

3. For test details - see Table 3-4 and 3-5.

4. Between one and four welds in each specimen were sectioned and examined.

5.1.1.3 Sustained Flight Load Test. Several simulated Centaur joint Specimens were corroded and tested at simulated flight loads. The loading program consisted of applying a tension load of 135 ksi for 16 hours. Three times during the test the load was reduced to zero, simulating the variation of load in flight. After the 135 ksi exposure, the load was increased to 160 ksi for 16 hours. The load was relaxed three times as before. Conditions and results of the tests are presented in Table 5-3.

The test specimens, which were corroded to the point where X-ray analysis indicated corrosion equal to or worse than that observed by X-ray analysis of the 2D (AC-6) tank joints, passed the tests without failure. However, subsequent metallurgical analysis of the test specimens revealed that the X-ray indications were not cracks as found in similar production tank structure. Since the specimens may not have been corroded sufficiently, the tests were inconclusive. Other tests with corroded specimens more similar to production tank corrosion are in process.

5.1.1.4 Sustained and Ultimate Loading Tests. Four specimens cut from the aft bulkhead of a scrapped tank were tested first statically at approximately 135 ksi in two applications for total load durations as indicated in Table 5-4. They were then tested to ultimate. The results of this testing are shown in Table 5-4. Specimen W3-3 selected from an uncorroded portion of the tank was used as a control specimen.

5.2 FORWARD BULKHEAD TANK EID 55-7534-1 (T-6)

5.2.1 SPECIAL TESTS. From November 2, 1962 to December 15, 1962 special tests were conducted on the forward bulkhead of test tank T6 (7534-1) in order to evaluate the structural integrity of installed plugwelds. A total of 101 pressure cycles at full flight pressures were conducted. These tests were conducted at GD/C, Point Loma facility where the tank was subjected to salt air environment. Although 40 percent of the spotwelds examined showed corrosion, no failures occurred during testing. Figure 5-1 shows the extent of the corrosion noted in three X-ray tests on September 1, 1964, October 26, 1962, and February 5, 1963. (See also Appendix C-30). This tank is similar to the flight tanks but has been subjected to considerably more load cycles and more severe corrosion. This demonstrates a wide margin of safety for the flight tanks since no failure occurred under these adverse conditions.

5.3 CONTINUED TESTING

Tests are continuing to determine standards for the acceptable amount and extent of tank corrosion. Tests are now in progress to determine the effects of corroded spotwelds on the static, fatigue, and sustained load capability of structural tank joints. The results of the remaining tests, which are in process, shall be reported in the subsequent addendum to this report. The tests now in progress are herein defined.

5.3.1 STRESS CORROSION. Table 5-5 shows the combination of chemical reagents used to produce corrosion in spot welded joints of sixteen 301 CRES, 3/4 H specimens. There are presently under load at a stress level of 20 ksi, and will be

TABLE 5-3. SUSTAINED LOADING TEST

Code I. D.	Specimen Matl. & Gage	Corrodent Used	Level ksi	Duration hr	** Method	Temp	Corrosion* Start 1/6/65 P	Start 1/6/65 C	Finish 1/15/65 P	Finish 1/15/65 C	Total Spots Examined	Remarks
1	EH Type 301 CRES .010	None	135 160	16 16	3~ 3~	-320	0 0	0 0	0	0	68	Control Specimens No failure
2	↓	None	135 160	16 16	3~ 3~	↓	0	0	0	0	↓	↓
3	↓	None	135 160	16 16	3~ 3~	↓	0	0	0	0	↓	No failure
4	↓	Lectroetch #260A	135 160	16 16	3~ 3~	↓	17	26	15	41	↓	No failure
5	↓	Lectroetch #260A	135 160	16 16	3~ 3~	↓	13	22	16	37	↓	↓
6	↓	Lectroetch #260A	135 160	16 16	3~ 3~	↓	6	22	17	26	↓	↓

* Legend
P = Pits
C = Cracks (By X-ray evaluation)

** Load reduced to zero three times.

TABLE 5-4. ULTIMATE LOADING TESTS

Code ID	Specimen Matl. & Thickness	Specimen Condition**	Test Conditions Level ksi	Total Duration Hr	*** Method	Temp. °F	Remarks
W3-1	301 3/4 H .018 obtained from 7547-1 Aft Bulkhead	Corroded	133.6 239.7	16	2~	-320	No leaks (Ult) Failure in splice joint
W3-2		Corroded	135.1 240.8	16	2~		One leak (Ult) Failure in splice joint *
W3-3		Not Corroded	134.7 261.9	16	2~		No leaks (Ult) Failure in splice joint
W-11-1		Corroded	136.1 238.8	16	2~		No leaks (Ult) Failure in splice joint at first row of spotwelds

*Failure occurred along the portion of the joint where no corrosion was evident.

**Corrosion due to natural tank environment. ***Load reduced to zero twice.

TABLE 5-5. STRESS CORROSION TEST

Chemical Reagents:

1. Lectroetch 2611A
2. Lectroetch 260A
3. Lectroetch ENO. 1
4. Lectroetch B10
5. Bubble fluid red X
6. Cleaner TEC 901 plus mill marking ink
7. Cleaner TEC 902
8. Ink, Layout dykem

Test Conditions:

1. Material - 301 CRES, 3/4 Hard (0-71005), 018 gage
2. Stress level - 20 ksi
3. Test duration - 6 months
4. No. of specimens - 16 (2 per reagent)
5. Start date - 4/28/65
6. X-ray examination schedule - Before start 4/19/65. Then at 2 weeks, 2 months and 6 months after first X-ray.

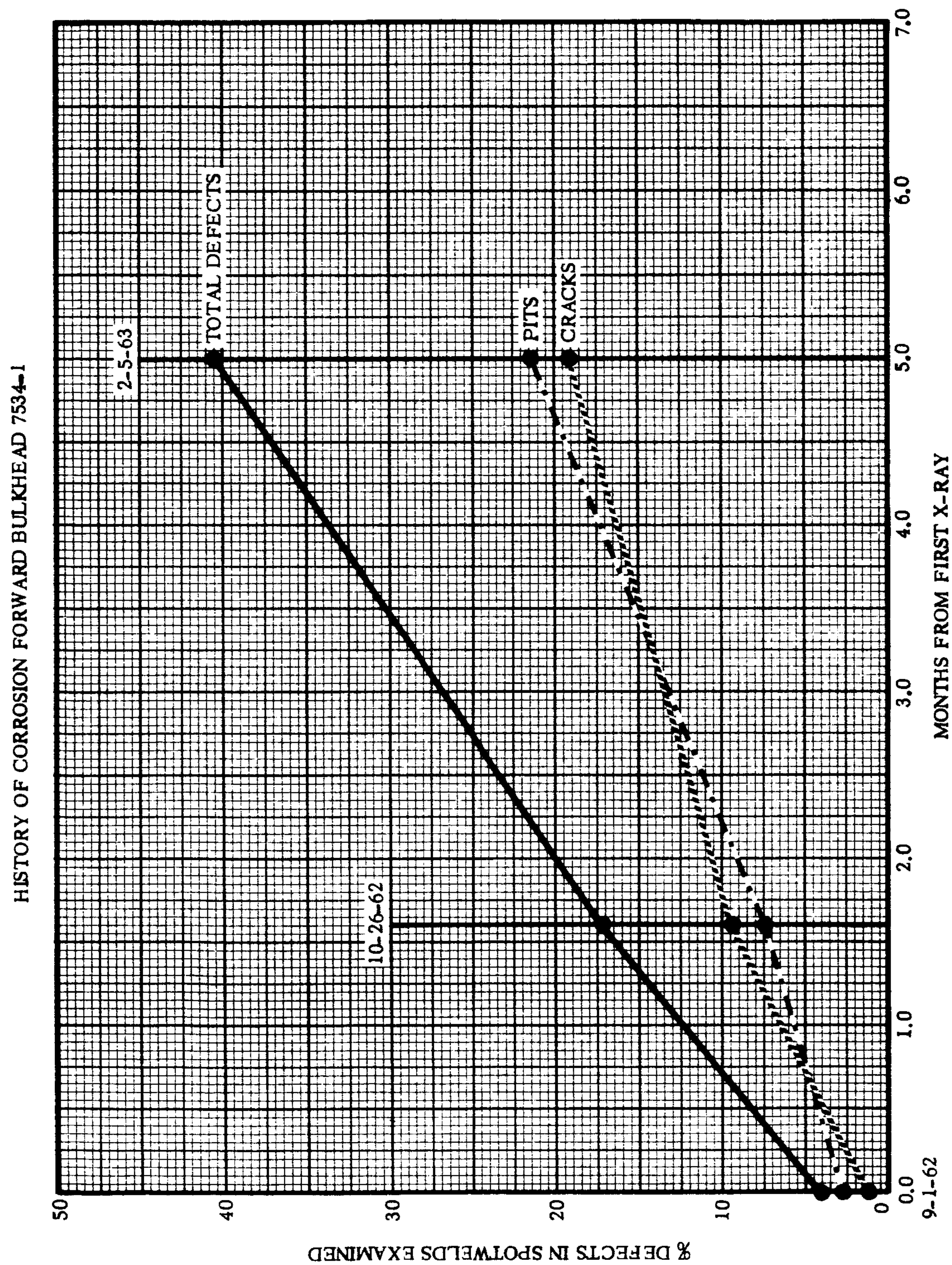


Figure 5-1. Test Tank 7534-1 (T-6)

exposed to an atmosphere environment for six months. The material and test conditions are representative of the aft bulkhead at standby pressure. A radiographic examination schedule is contained in Table 5-5.

5.3.2 STATIC AND FATIGUE LOAD TEST. Various levels of corrosion will be introduced into the specimens using chemical and mechanical conditions as outlined in Table 5-6. The following definitions represent those corrosion levels:

a. Clean - No corrosion (control specimens).
b. Mild - General pitting condition as found in tanks.
c. Moderate - Worst pitting and cracking condition found in tanks.
d. Severe - Excessive pitting and radial cracking condition not found in tanks.

Both aft bulkhead and constant skin material (301 CRES, 3/4 H, and extra hard, respectively) will be corroded to these levels using Lectroetch 260A as the corrodent. Radiographic examination will be used to monitor the amount and type of corrosion. The various corrosion levels revealed by the X-ray images will be compared to those found in tanks and in previous test specimens. Table 5-7 shows the static and fatigue test program which will be used to evaluate the effects of various corrosion levels. Both static and fatigue testing will be done at -320° F for 3/4 H specimens and -423° F for the extra hard specimens to simulate the condition for the aft and forward bulkhead, respectively.

TABLE 5-6. CONDITIONS FOR INDUCED CORROSION PRIOR TO STATIC AND FATIGUE LOAD TESTING

Corrosion Level	Reagent	Stress Level*	Time*
Clean	None	0	0
Mild	Lectroetch 260A	20 ksi	2 weeks
Moderate	Lectroetch 260A	80 ksi	2 weeks
Severe	Lectroetch 260A	120 ksi	2 weeks

* May be adjusted to produce required corrosion levels.

TABLE 5-7. STATIC AND FATIGUE LOAD TEST

301 CRES, 3/4 Hard (0-71005), .018 Gage			
Static Test:			
Corrosion Level	No. of Specimens	Temp (° F)	
Clean	2	-320	
Moderate	2	-320	
Severe	2	-320	
Fatigue Test:			
Corrosion Level	No. of Specimens	Temp (° F)	Stress Level ksi
Clean	3	-320	0-135
Mild	3	-320	0-135
Moderate	3	-320	0-135
Severe	3	-320	0-135

301 CRES, Extra Hard (0-71022), .014 Gage			
Static Test:			
Corrosion Level	No. of Specimens	Temp (° F)	
Clean	2	-423	
Moderate	2	-423	
Severe	2	-423	
Fatigue Test:			
Corrosion Level	No. of Specimens	Temp (° F)	Stress Level KSI
Clean	3	-423	0-135
Mild	3	-423	0-135
Moderate	3	-423	0-135
Severe	3	-423	0-135

SECTION VI

CONCLUSIONS

6.1 CORROSION - CAUSE AND PREVENTION

6.1.1 CAUSE. Spotweld corrosion is caused by corrosive solutions entrapped between the faying surfaces of spot-welded joints. Centaur tank corrosion was caused by corrosive elements contained in processing materials used during tank fabrication.

6.1.1.1 Tank Structure History. AC-4 through AC-8 Vehicles, having been examined and studied for verification, were approved for flight, and continuance of tank fabrication, since there was no evidence to indicate that tank stress levels were exceeded due to weakening or failure of spotwelds at this time. However, it was determined that preventative measures should be studied, tested, and implemented as soon as possible to deter corrosive elements from becoming more severe. In addition, the tanks were monitored periodically by X-ray for corrosion initiation and growth.

6.1.2 PREVENTATIVE MEASURES. Corrosion can best be prevented by elimination of the corrosive solutions in the faying surfaces. The following means of accomplishing this were considered:

a. Introduction of corrosion inhibitor environment, such as ammonia gas, into the tank following tank closure and retention of this environment at all times during tank storage.

b. Application of corrosion inhibitor, such as WD-40, to all outside tank surfaces immediately following fabrication.

c. Fabrication of tanks under controlled cleanness conditions, thus minimizing possibility of introducing corrosive elements into faying surfaces.

d. Elimination, as far as possible, of corrosive elements from the tank fabrication processes.

Item a (ammonia) above, was found ineffective in preventing or inhibiting corrosion unless inhibitor environment was continually maintained, which was not found practical. Item b (WD-40) was found effective for outer surfaces, but not LO_2 compatible. Therefore, WD-40 is used on external tank surfaces only. Items c and d (maintenance of tank cleanness and elimination of corrodents) have been initiated and proven effective. This is reflected in the small amount of corrosion found in tank 7D (partially manufactured using this "super clean" process) and the lack of corrosion in tank 8D (completely manufactured using the new process). Refer to the radiographic summaries in Appendix B.

Tank 9D, completely fabricated using the new process, is presently undergoing 100% X-ray. Results of the radiographic inspection will be forwarded upon completion.

SECTION VII

REFERENCES

1. Metallurgical and Repair Weld Investigation, GD/C Report No. AR-504-1-535.

2. Failure Analysis of Boiloff Valve, GD/C Report No. AR-504-1-541.

3. Failure Analysis of Centaur Boss 55-42328-1, GD/C Report No. AR-504-1-550.

4. Ammonia as a Corrosion Inhibitor for Centaur Tanks, GD/C Report No. AR-504-1-549.

5. TEC 901 - TEC 902 Corrosion Test, GD/C Report No. AR-504-1-538.

6. Phase III Report Tank Corrosion Program, GD/C-BNZ65-024.

7. Sustained Load and Fatigue Tests, Materials Research Memo # M-372.

8. Test Program To Determine The Effect of Existing Corrosion Damage on Tank Structural Integrity, GD/C Report No. ACS-65-39.

9. Corrosion of Stainless Steel Spotwelds by Processing Chemicals, GD/C Report No. AR-572-1-568.

10. Phase IV Interim Report, Tank Corrosion Prevention Program, GD/C-BNZ65-012.

11. Phase IV Interim Report, Tank Corrosion Prevention Program, GD/C-BNZ65-012 Addendums I, II, and III.

APPENDIX A

A-1.1 TEST RESULTS

A-1.1.1 SUMMARY, MAPS, AND PLOTS. The X-ray data obtained during the corrosion program is presented in three forms:

a. Tank Corrosion Summary.

b. Corrosion Location.

c. Corrosion Plots.

Presented in upcoming appendices is detailed information, supported by charts, tables, and graphs, on the X-ray data.

APPENDIX B

B-1.1 TANK CORROSION SUMMARY

B-1.1.1 FLIGHT TANKS AND TEST TANKS. The Tank Corrosion Summary shows all of the X-ray inspections on each tank made to 15 July 1965. These tanks are divided into flight tanks and test tanks. This summary shows that the tanks (7D, 8D, and 9D) manufactured under the new "clean" standards show a negligible amount of corrosion. Following, are the tables.

DATE 15 JULY 1965

-RAY	CORROSION					X-RAY			CORROSION				
EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
				MO	DAY							MO	DAY
Plugs	316	9	4			2-5-63		Plugs	327	70	62		
Plugs	240	18	23										

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED	
			DATE	METHOD
T6	7534-1 was 7524-1 Scrapped Fwd bulkhead Tank used for plug weld test	Fwd		
		C.S.		
		Aft		
2C	7539-1 AC-4 panel cryo test	Fwd		
		C.S.		
		Aft	2-26-63	B.W.***
1B	7540-1 Bulkhead reversed, stored at Sycamore.	Fwd		
		C.S.		
		Aft		
3C	7542-1 used on Pt. Loma struct. test and nose fairing sep. at "K" tower. Stored at Plt. 2	Fwd	4-9-63	
		C.S.	6-14-63	
		Aft	5-18-63	B. W.
7C	7543-1 spare stored at Plt. 2	Fwd	9-18-63	B. W.
		C.S.	10-31-63	B. W.
		Aft	11-13-63	B. W.

*** B. W. indicates beryllium window X-

STATUS OF BULKHEAD AND SKINS	TANK CLOSURE COMPLETED	TESTING	X-	
	DATE		DATE	METHOD
Attached	9-27-62	101 cycles cryogenic (LH_2) test	9-1-62 10-26-62	
Attached	9-27-62			
Attached	9-27-62			
Attached	4-22-63	Demonstrated struct integrity of 219/408 joint applied limit loads Rpt # 55B2669-1, -2		
Attached	4-16-63			
Attached	12-6-62	2-26-63 AC-2 hot firing		
Attached	12-6-62			
Attached	6-22-63	Demonstrated struct integrity of 219/408 joint applied limit loads Rpt # 55B3308 and 55B3187		
Attached	6-22-63			
Attached	6-21-63			
Attached	11-21-63	"C" series tank completed 11-21-63. No testing		
Attached	11-21-63			
Attached	11-13-63			

ray method.

...RROSION				X-RAY			CORROSION				
PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
		MO	DAY							MO	DAY
3	1	3	17								
1	2	2	6								
52	14	1	13	9-15-64	B. W.	100% except MSC. Brackets	19,800	238	83	2	28
5	3	2	8								

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED DATE	IN-PROCESS X-RAYS COMPLETED METHOD	STATUS OF BULKHEAD AND SKINS
2B	AC-2 Successfully flown 11-27-63	Fwd	11-8-62	B. W.	Attached
		C. S.	12-13-62	B. W.	Attached
		Aft	11-30-62	B. W.	Attached
1C	AC-3 Successfully flown 6-30-64	Fwd	2-17-63	B. W.	Attached
		C. S.	3-15-63	B. W.	Attached
		Aft	3-18-63	B. W.	Attached
4C	AC-4 Successfully flown 12-11-64	Fwd	5-3-63	B. W.	Attached
		C. S.	6-28-63	B. W.	Attached
		Aft	7-30-63	B. W.	Attached
6C	AC-5 Destroyed on launch pad 12-11-64	Fwd	8-29-63	B. W.	Attached
		C. S.	10-10-63	B. W.	Attached
		Aft	11-21-63	B. W.	Attached
1D	Designated for AC-10 in final assembly	Fwd	2-10-64	B. W.	Attached
		C. S.	2-5-64	B. W.	Attached
		Aft	2-21-64	B. W.	Attached

*Double Wall Radiograph

TANK CORROSION SUMMARY
TEST TANKS (Continued)

TANK CLOSURE COMPLETED	TESTING	X-RAY			CO
DATE		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED
7-15-64	Started 16 cycle "D" series fatigue test later on, struct integ. of 219/412 joints limit loads (in process)	9-15-64	B.W.*	100%	9,350
7-15-64		9-15-64	B.W.*	10%	2,100
7-15-64		7-20-64	B.W.*	100%	19,800
4-9-64	Start test in support of AC-6 struct integ. Fwd & aft bulkhead and AC-4 payload adapter test.				
4-9-64					
4-9-64					
		8-4-64	B.W.*	100%	19,800

TANK CORROSION SUMMARY
FLIGHT TANKS

TANK CLOSURE COMPLETED DATE	TESTING	X-RAY DATE	X-RAY METHOD	EXTENT OF X-RAY	COF APPROXIMATE SPOTS EXAMINED
12-19-62	Cryo-tested at Pt. Loma 1-29-63	2-1-63	B.W.	100%	9,350
12-19-62		2-1-63	B.W.	100% except last skin	13,400
12-19-62		2-1-63	B.W.	All splice plates	16,000
3-19-63	Cryo-tested at Pt. Loma 4-30-63	5-4-63	B.W.	100%	9,350
3-22-63		5-4-63	B.W.	100% except final skin +10% of brackets	16,200
3-22-63		5-4-63	B.W.	3/4 doublers 2/3 brackets	3,300
7-10-63	Cryo-tested at Pt. Loma 7-30-63	8-6-63 Post-cryo		1. All cir. str. welds Stations 172,219,282,344 and 408	6,100
7-10-63				2. Splices on const. skin between Stations 251 and 344	11,700
				3. 1/3 brkt. conical skin of fwd bulkhead 1/2 brkt. on const. skin	0
10-30-63	Cryo-tested at Pt. Loma 12-3-63		.		
10-30-63					
10-30-63		10-28-64	B.W.*	Approx. 7%	1,440
3-12-64	No test prior to intermediate bulkhead reversal	8-6-64	B.W.	100%	9,400
3-12-64		8-6-64	B.W.	Splice-doubler welds 1-6	3,600
3-12-64		7-27-64	B.W.	100%	19,800

B-4-2 B-4-

DATE 15 JULY 1965

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED		STATUS OF BULKHEAD AND SKINS
			DATE	METHOD	
4D	7545-1 Re-identified; was AC-8. Moved to struct test Pt. Loma "K" tower	Fwd	5-28-64	B. W.	Attached
		C. S.	7-9-64	B. W.	Attached
		Aft	6-17-64	B. W.	Attached
T9	7550-1 "D" Fwd & Aft Bulkhead Stub tank "M" tower Pt.Loma	Fwd			Attached
		C. S.			Attached
		Aft			Attached
5D	7562-1 unlatch test article	Fwd	6-15-64	B. W.	Attached
		C. S.	8-14-64	B. W.	Attached
		Aft	5-26-64	B. W.	Attached

*Beryllium Window

DATE 15 JULY 1965

(COR)ROSION				X-RAY			CORROSION				
PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
		MO	DAY							MO	DAY
19	10	2	23								
0	0	2	18								
14	0	3	0								
1	5	1	8								
5	1	1	19								
2	0	1	16								
		0	3								
		1	9								
13	6	0	18								
30	2	5	26	2-11-65	R.A.	95%	8,900	71	11	12	1
12	8	6	1	2-11-65	R.A.	Welds sta. 219 thru 344	15,800	25	0	12	6
110	32	5	6								

RROSION				X-RAY			CORROSION				
PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
		MO	DAY							MO	DAY
71	12	13	4								
13	12	2	19	2-11-65	R.A.	Approx.40%	7,900	0	0	6	10
0	0	7	23	4-20-65	B.W.	Approx. 7%	1,440	0	0	8	19
10	11	8	28	7-8-65	B.W.*	Approx. 7%	1,440	0	0	11	8
0	0	2	25								
0	0	1	8	8-1-64	B.W.	100%	20,600	0	0	4	11
	156 Total	2	0	8-1-64	B.W.	100%	19,800	143	69	4	12
16	12	6	5	10-29-64	B.W.*	5% monitoring program	910	16	12	7	10
10	4	9	18	2-8-65	B.W.*	7% monitoring program	1,440	31	8	10	19

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CON-STANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED		STATUS OF BULK-HEAD AND SKINS
			DATE	METHOD	
2D (Continued)		Fwd			
		C.S.			
		Aft			
3D	Designated for AC-7	Fwd	3-8-64	B.W.	Attached
		C.S.	4-28-64	B.W.	Attached
		Aft	4-20-64	B.W.	Attached
		Fwd			
		C.S.			
		Aft			
		Fwd			
		C.S.			
		Aft			
		Fwd			
		C.S.			
		Aft			

*Double Wall Radiograph

TANK CORROSION SUMMARY
FLIGHT TANKS (Continued)

TANK LOSURE COM-PLETED	TESTING	X-RAY			CO
DATE		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED
		3-14-65	R.A.***	Approx. 10%	950
2-21-65		10-20-64	B.W.	100%	19,800
		3-24-65	B.W.*	Approx. 7%	1,440
		4-29-65	B.W.	Approx. 1%	150
3-23-64	Cryo-tested at Edwards 5-7-64	5-18-64	R.A.	100% Aft of Station 172	8,400
4-20-64		5-15-65	R.A.	80%	16,500
4-20-64		5-18-64	R.A.	Approx. 40%	7,900
		9-29-64	B.W.*	5% monitoring program	910
		1-6-65	B.W.*	2% monitoring program	480

TANK CORROSION SUMMARY
FLIGHT TANKS (Continued)

TANK LOSURE COM- PLETED DATE	TESTING	X-RAY DATE	X-RAY METHOD	EXTENT OF X-RAY	CO APPROXIMATE SPOTS EXAMINED
		3-2-65	B. W.*	7% monitoring program	1,440
5-2-64	Cryo-tested at Edwards 6-10-64	7-15-64	B. W.	100% Aft of Station 172	9,350
5-2-64		7-15-64	B. W.	100%	20,500
5-1-64		7-15-64	B. W.	100%	19,800
		8-26-64	B. W.	100%	9,350
		8-26-64	B. W.		2,050
		8-26-64	B. W.	100%	19,800
		11-2-64	R. A.	Partial	8,600
		2-8-65	B. W.*	3 1/2% monitoring program	600

0-6-2

DATE 15 JULY 1965

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED		STATUS OF BULKHEAD AND SKINS
			DATE	METHOD	
1D (Continued)		Fwd			
		C. S.			
		Aft	7-31-64	B/W	Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			
2D	AC-6 erected on Complex 36B at ETR	Fwd	2-23-64	B. W.	Attached
		C. S.	3-20-64	B. W.	Attached
		Aft	3-19-64	B. W.	Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			

*Double Wall Radiograph
**New Aft Bulkhead Installed
***R. A. indicates rod anode X-ray method.

DATE 15 JULY 1965

RROSION				X-RAY			CORROSION				
PITS	CRACKS	TIME FROM 1ST X-RAY MO	DAY	DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY MO	DAY
31	8	11	13								
12	5	4	10								
1	0	4	0								
62	26	2	25								
29	9	5	18								
1	0	3	28								
153	57	4	4	9-29-64	B.W.*	6% monitoring program	1,176	65	21	5	9
144	49	6	12	1-6-65	B.W.*	3 1/2% monitoring program	600	18	6	8	16
18	6	9	18	3-25-65	B.W.*	Approx. 7%	1,440	34	8	12	16

[redacted]

0-6-3

RROSION				X-RAY			CORROSION					
PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
		MO	DAY							MO	DAY
1	4	4	4								
7	3	2	23								
13	5	8	12	2-8-65	B.W.	7% corrosion monitoring	1,440	1	0	9	21
1	0	10	24	4-20-65	B.W.*	Approx. 7%	1,440	1	0	12	3
1	0	14	22								
2	0	1	0	1-25-65	B.W.	100%	19,800	15	0	2	13
0	0	7	5								
0	0	-	-								
21	0	4	19	7-8-65	B.W.*	Approx. 7%	1,440	0	0	7	26

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED		STATUS OF BULKHEAD AND SKINS
			DATE	METHOD	
8D	Designated for AC-9 in final assembly.	Fwd	11-11-64	B. W.	Attached
		C. S.		B. W. & R. A.	Attached
		Aft	2-16-65	B. W.	Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			
9D	Designated for AC-12 in component stage	Fwd			Not Attached
		C. S.			Not Attached
		Aft	1-19-65	B. W.	Not Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			

TANK CORROSION SUMMARY
FLIGHT TANKS (Continued)

TANK CLOSURE COMPLETED	TESTING	X-RAY			CC
DATE		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED
10-30-64	Cryo tested at Pt. Loma	12-29-64	R.A.	100% except sta. 162 and dome brackets	8,900
10-30-64		12-29-64	R.A.	100% up to and including station 334	16,400
10-30-64		12-29-64	R.A.	60% including brackets	7,900
		3-11-65	B.W.*	Approx. 7%	1,440
		7-8-65	B.W.*	Approx. 7%	1,440
		12-11-64	B.W.	100%	19,800
		4-1-65	B.W.	100%	9,350
		4-1-65	B.W.	100%	20,500
		4-1-65	B.W.	100%	19,800

TANK CORROSION SUMMARY
FLIGHT TANKS (Continued)

TANK CLOSURE COMPLETED DATE	TESTING	X-RAY DATE	X-RAY METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	COR
		1-5-65	B.W.	Welds 1 thru 12 Areas 1 thru 9	19,000	
		3-10-65	B.W.	100%	19,800	
		11-12-64	B.W.	Welds 1 - 12 Areas 1 - 9	19,000	
		6-15-65	B.W.	100%	19,800	

 [redacted]

DATE 15 JULY 1965

TANK NUMBER	PRESENT DISPOSITION	BULKHEAD OR CONSTANT SKIN SECT.	IN-PROCESS X-RAYS COMPLETED		STATUS OF BULKHEAD AND SKINS
			DATE	METHOD	
6D	Designated for AC-8 in final assembly	Fwd	7-28-64	B. W.	Attached
		C. S.	9-9-64	B. W.	Attached
		Aft	4-17-64	B. W.	Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			
7D	AC-11 In final assembly	Fwd	8-26-64	B. W.	Attached
		C. S.		B. W. & R. A.	Attached
		Aft	11-12-64	B. W.	Attached
		Fwd			
		C. S.			
		Aft			
		Fwd			
		C. S.			
		Aft			

*Double Wall Radiograph

DATE 15 JULY 1965

ROSION				X-RAY			CORROSION				
PITS	CRACKS	TIME FROM 1ST X-RAY		DATE	METHOD	EXTENT OF X-RAY	APPROXIMATE SPOTS EXAMINED	PITS	CRACKS	TIME FROM 1ST X-RAY	
		MO	DAY							MO	DAY
0	0	10	19	2-6-65	B. W.	100%	19,800	0	0	11	20
				6-5-65	R. A. & B. W.	100%	9,400	0	0	3	19
				6-5-65	R. A. & B. W	95%	19,500	0	0	3	19
0	0	0	24	6-5-65	R. A. & B. W.	100%	19,800	0	0	3	19
0	0	1	5	1-19-65	B. W.	100%	19,800	0	0	2	6
0	0	4	26								

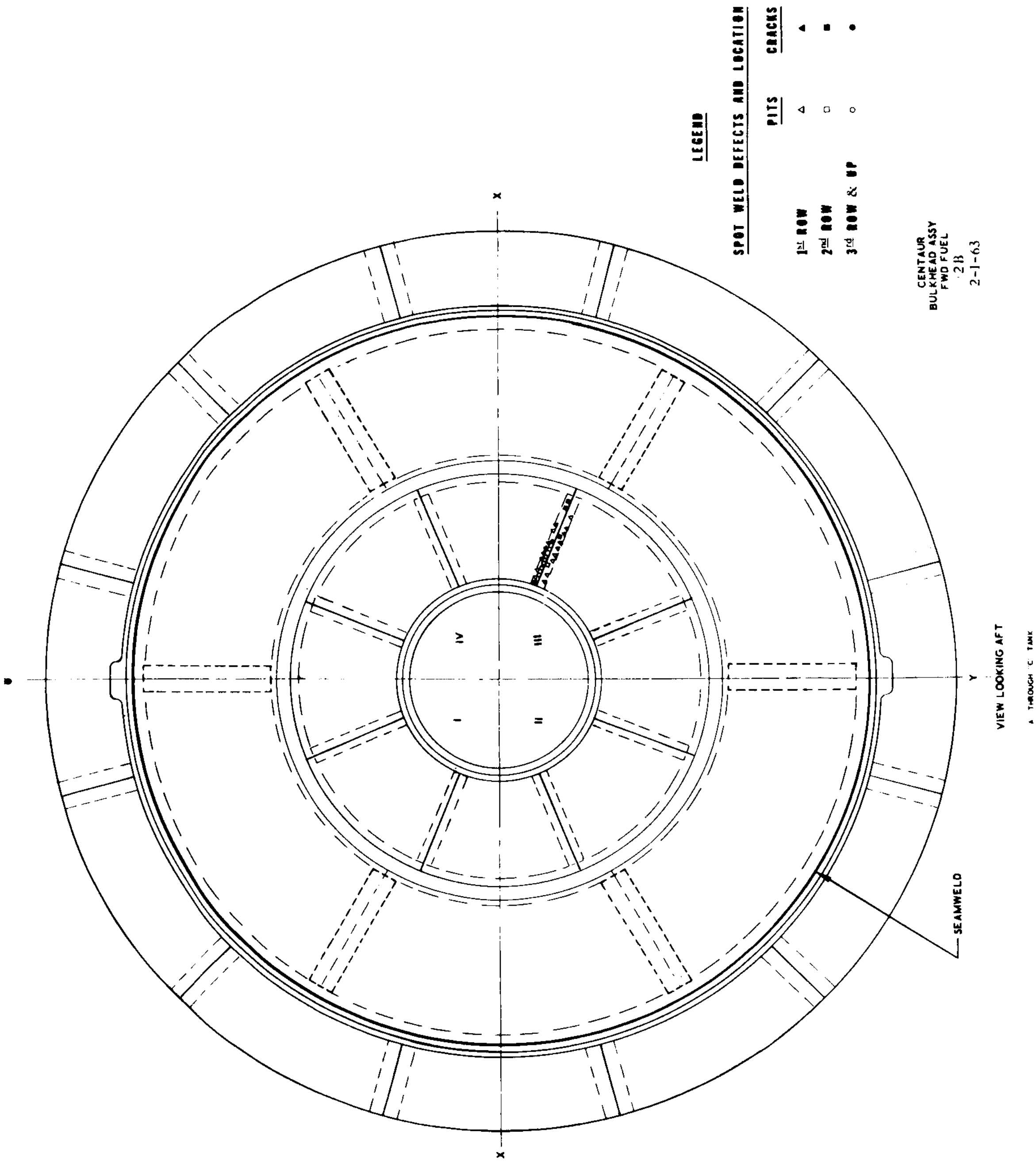
B-8-3

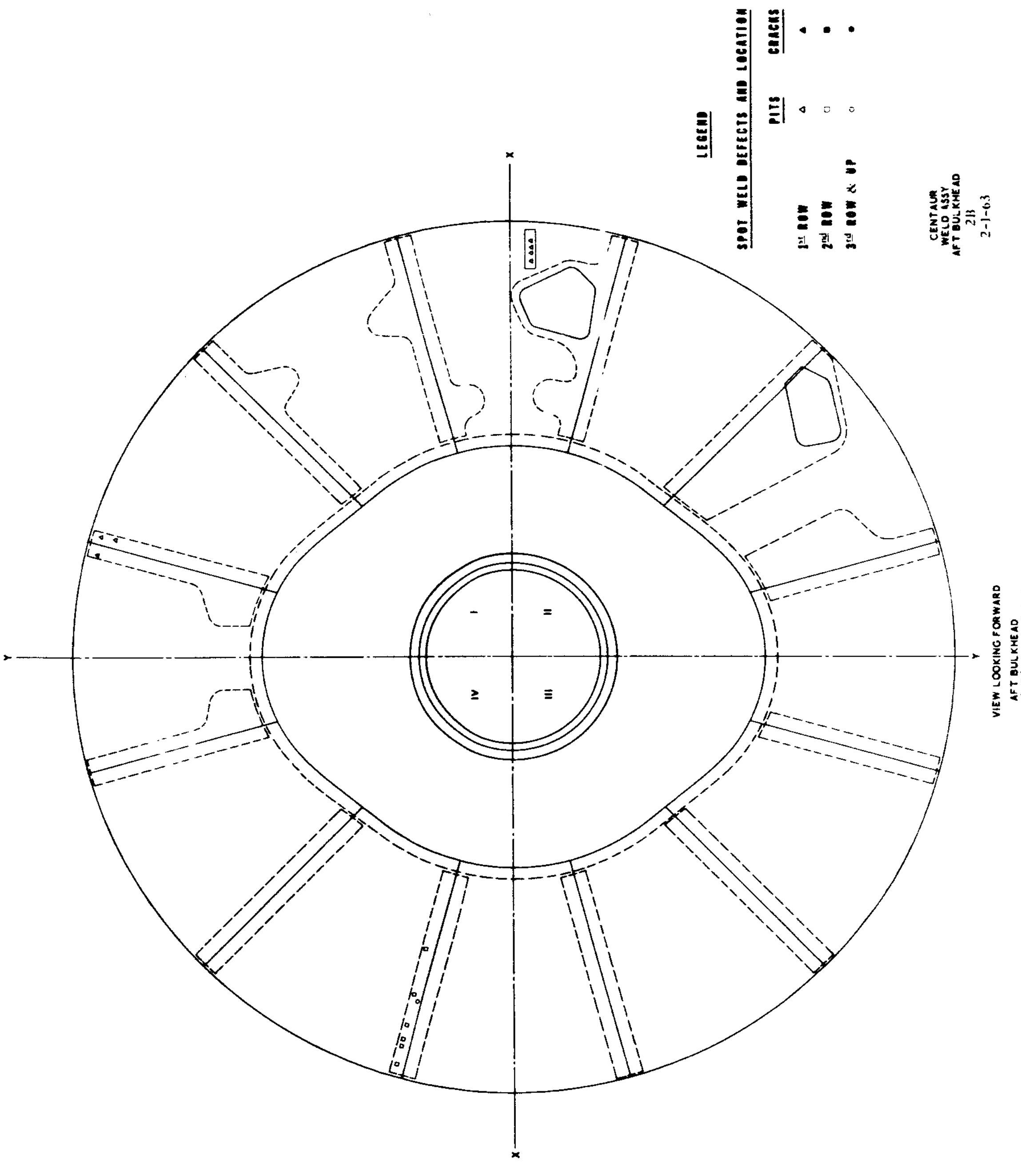
APPENDIX C

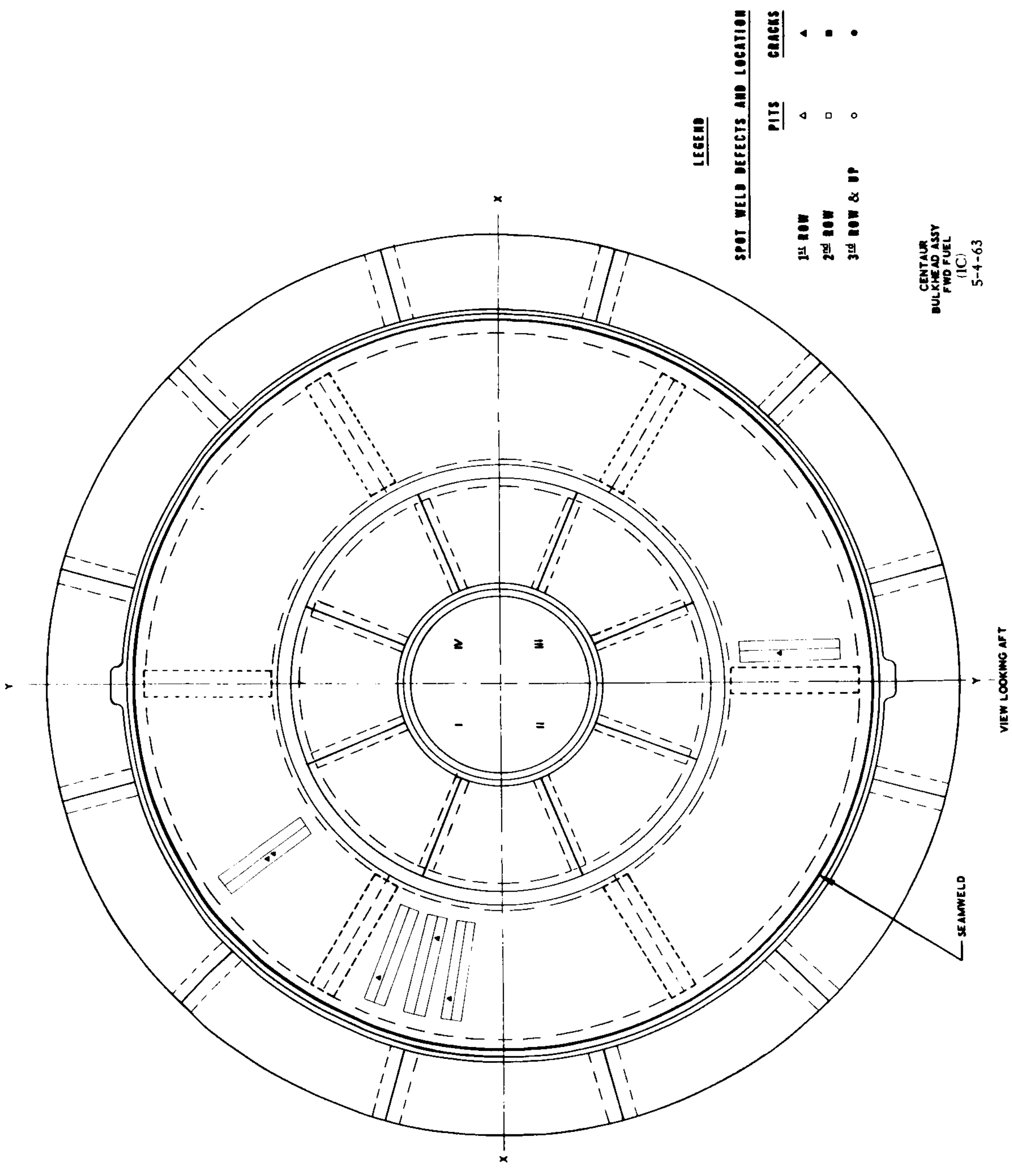
C-1.1 CORROSION LOCATIONS

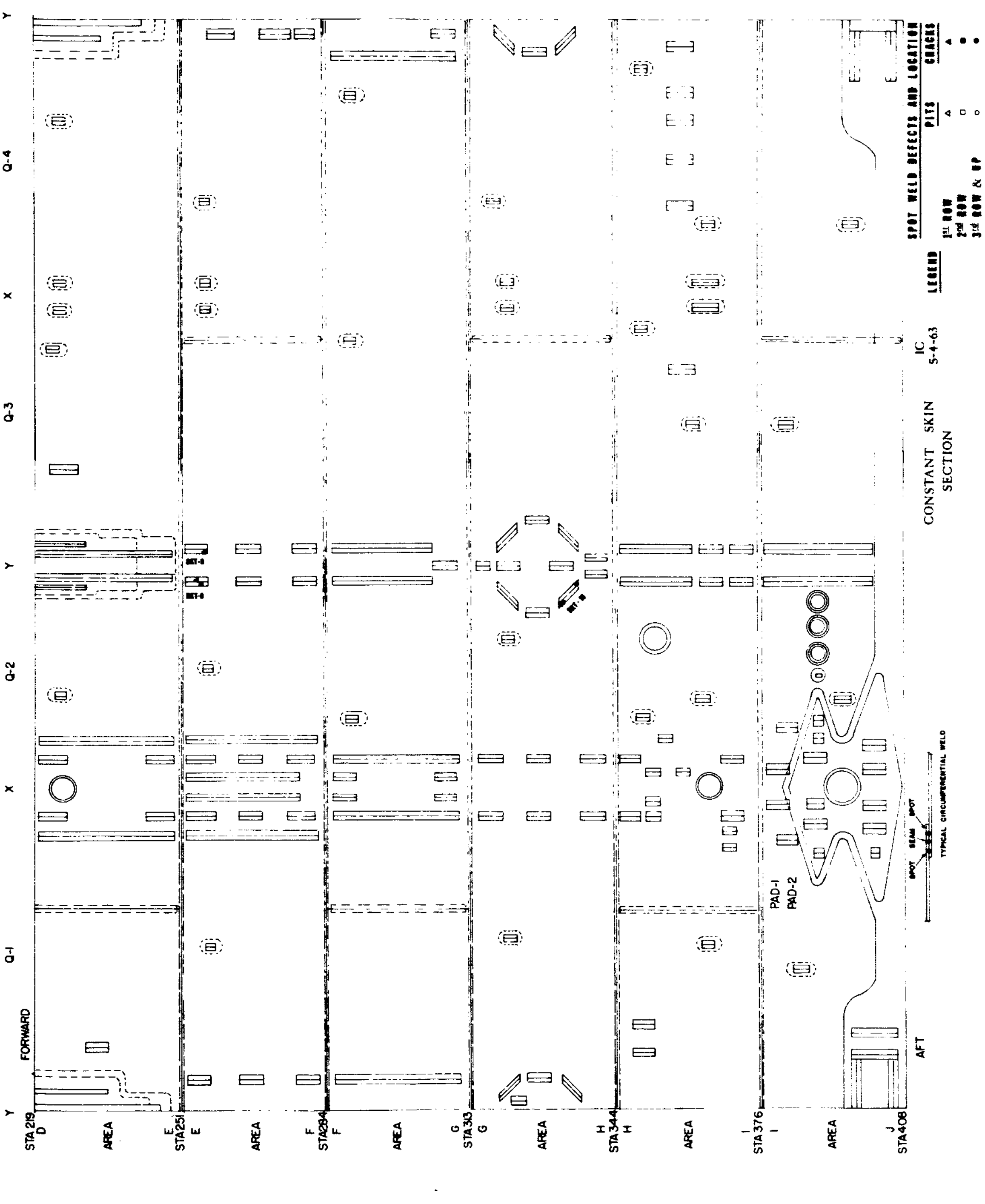
C-1.1.1 FORWARD BULKHEAD, CONSTANT SKIN SECTION, AND AFT BULKHEAD. Corrosion Locations, Appendix C, are shown in the forward bulkhead, constant skin section, and aft bulkhead maps. Maps were not prepared from X-ray examinations which illustrated only a few defects. These results are found in the Tank Corrosion Summary (Appendix B). These maps show if the defects are located in the first, second, third, or higher rows of spotwelds. A first-row-spotweld is in the first row after the edge of the faying surface. The majority of the load is carried by the first row of spotwelds.

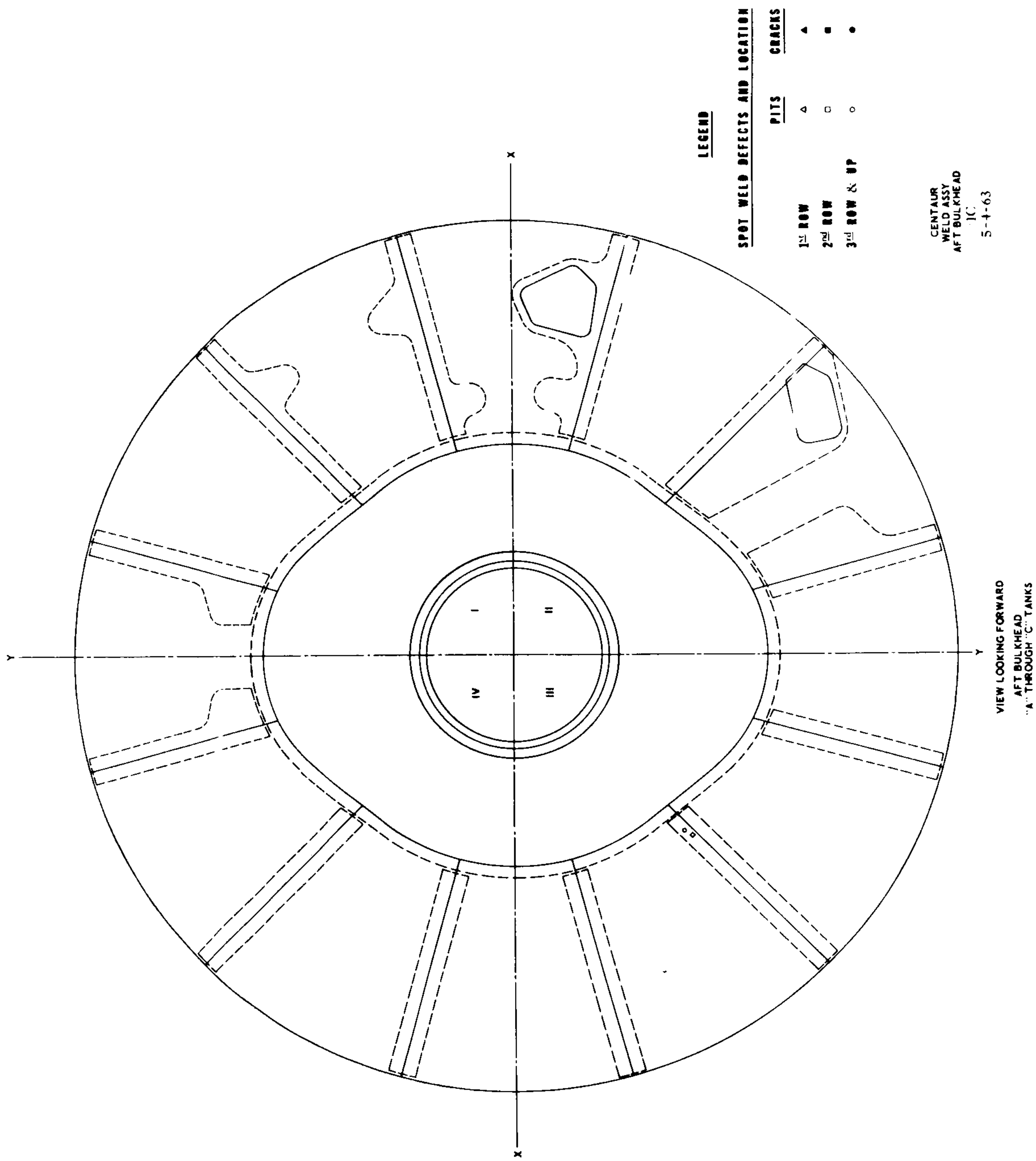
Maps, depicting these areas containing corrosion locations, herein follow.

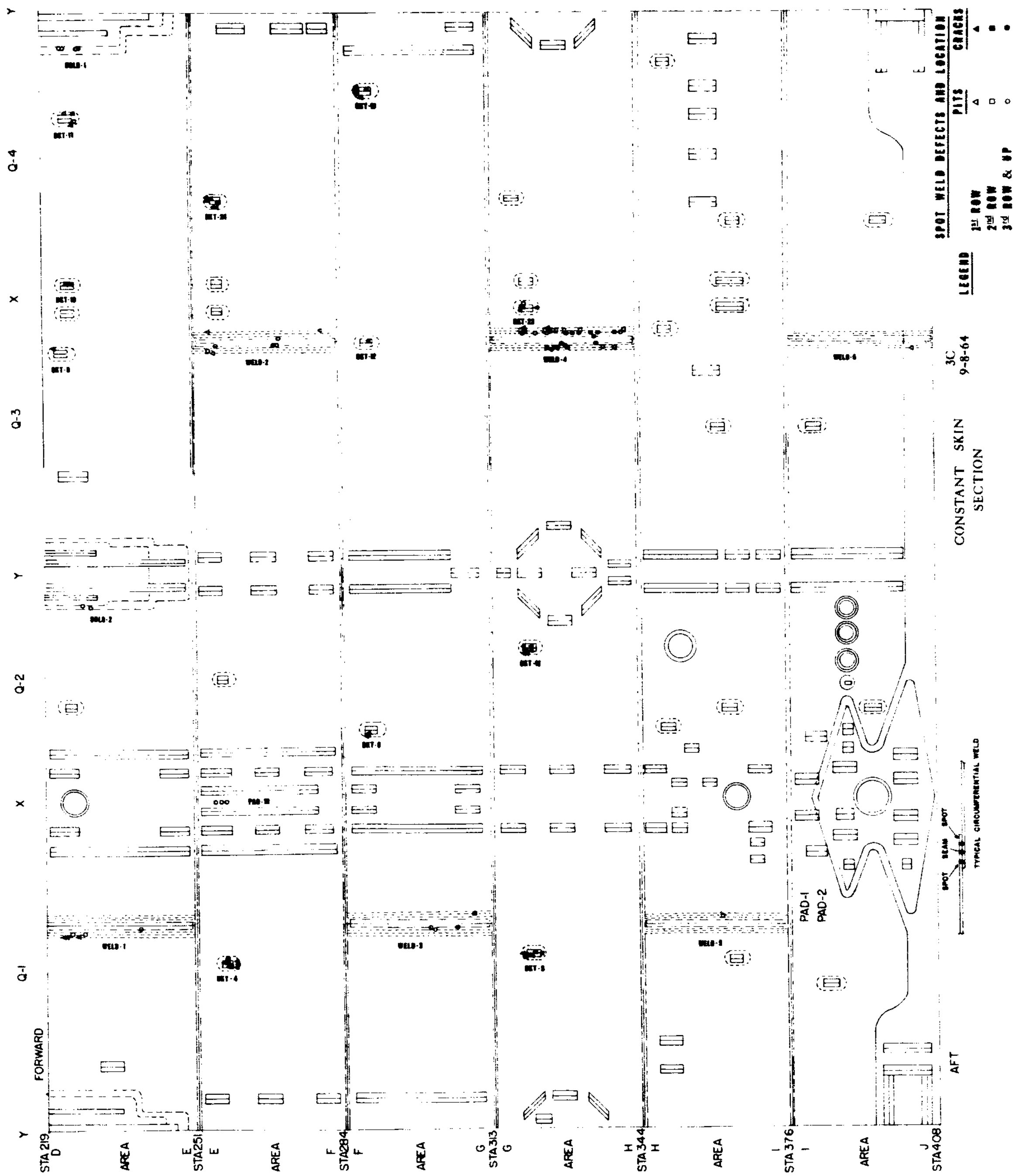

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
2B
2-1-63
VIEW LOOKING AFT
SEAMWELD
X
Y
I
II
III
IV

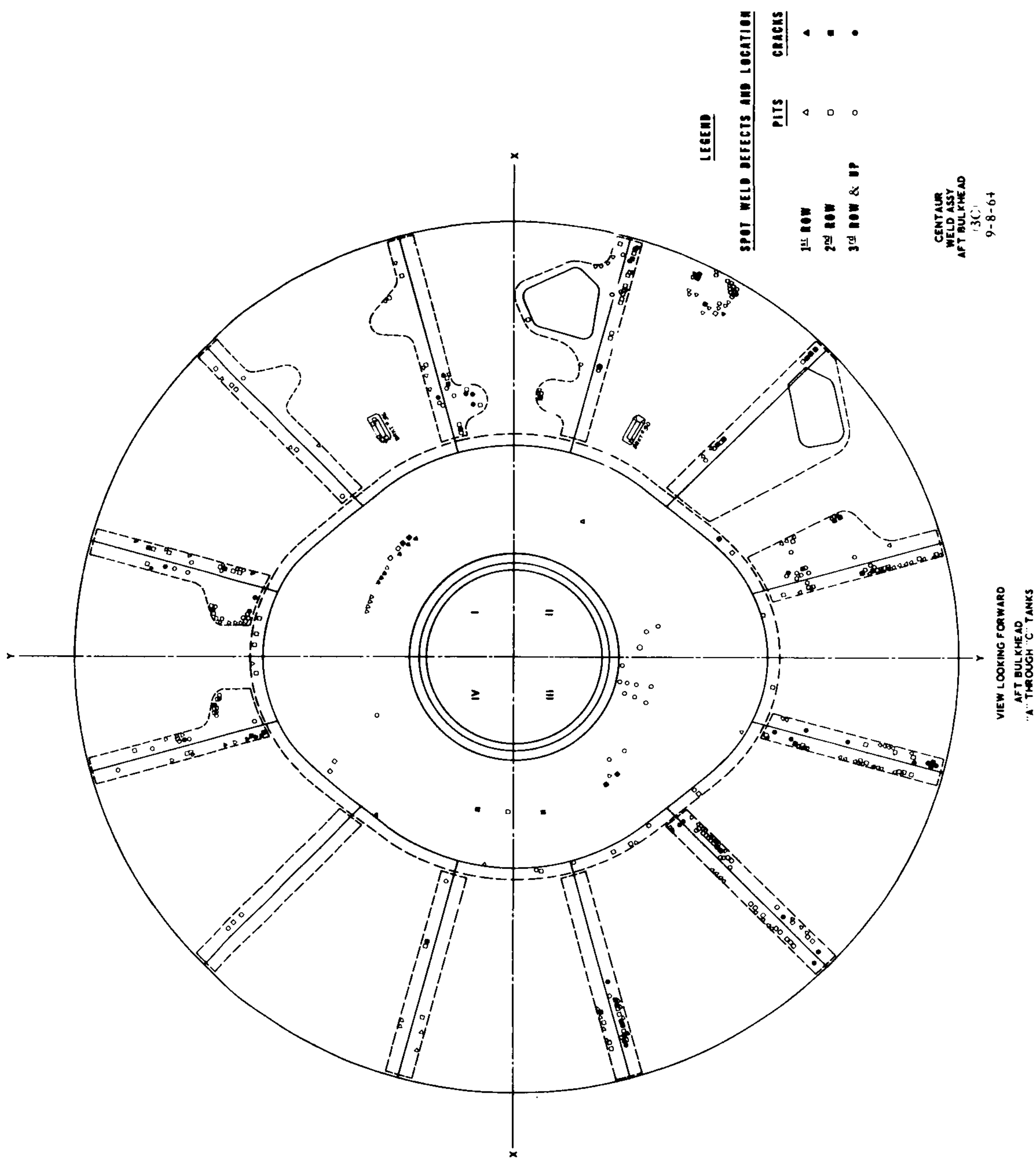

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
WELD ASSY
AFT BULKHEAD
2B
2-1-63
VIEW LOOKING FORWARD
AFT BULKHEAD
A THROUGH C TANKS
X
Y
I
II
III
IV

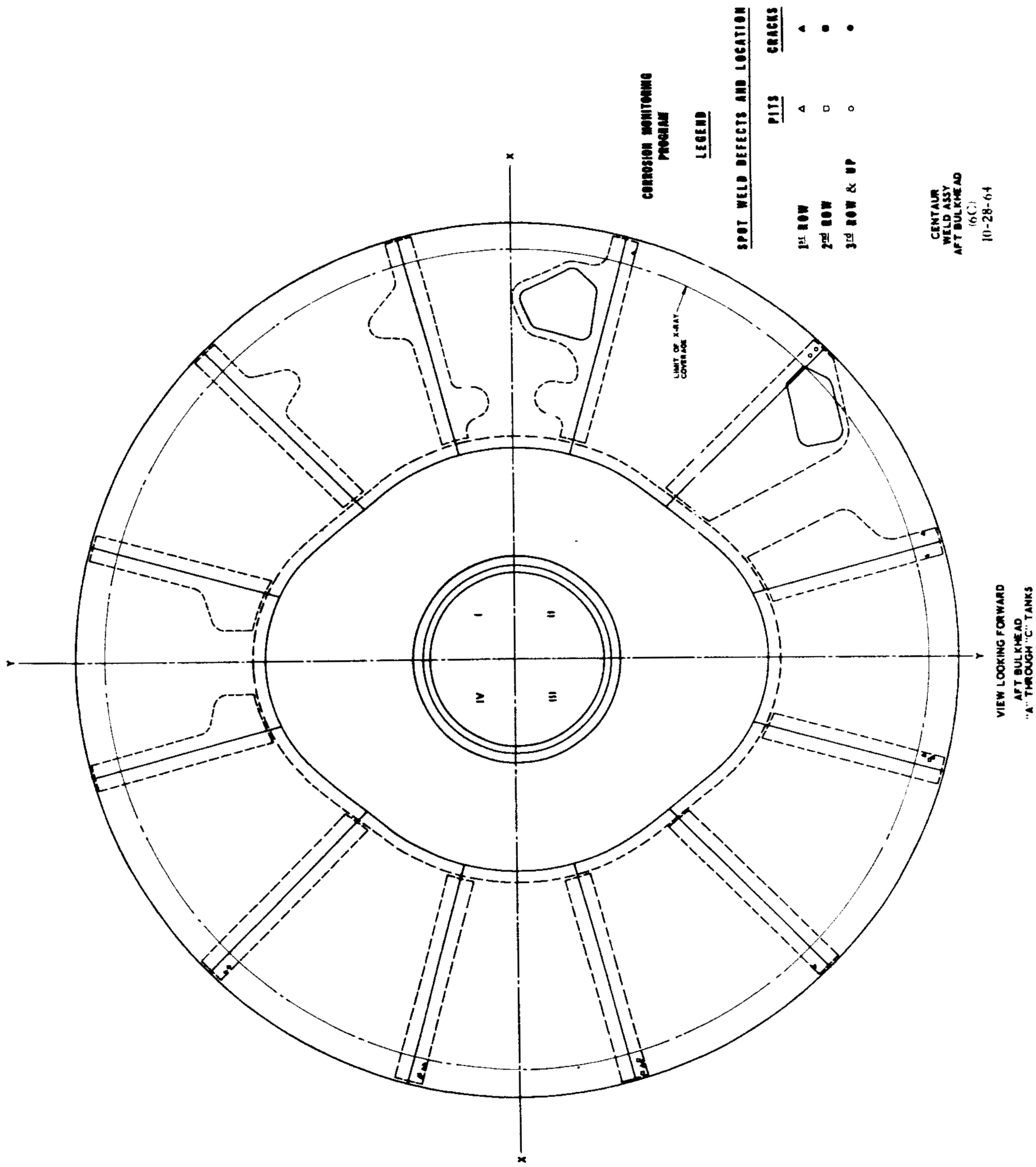

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
(1C)
5-4-63
VIEW LOOKING AFT
SEAMWELD
X
Y
I
II
III
IV

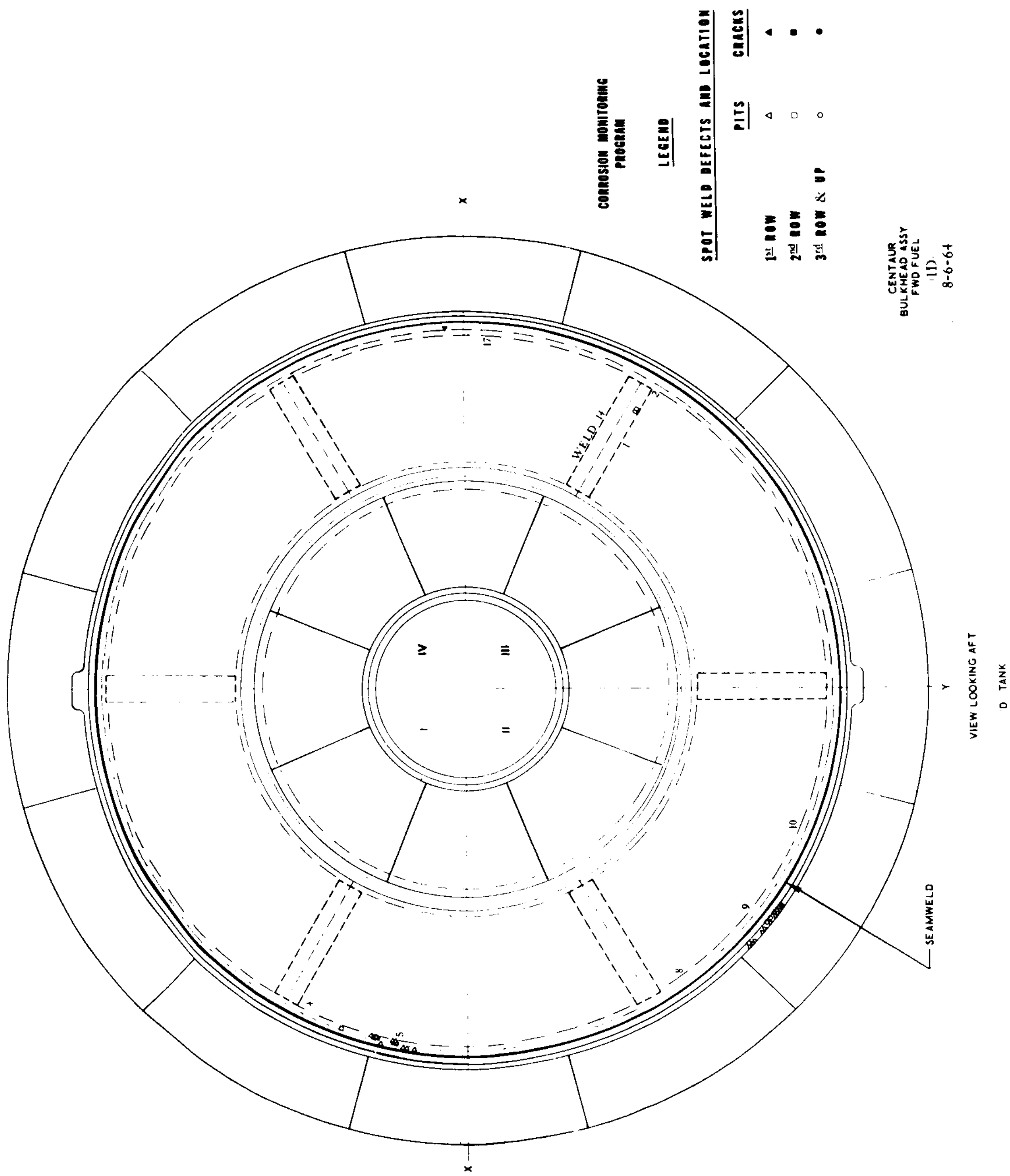

SPOT WELD DEFECTS AND LOCATION
LEGEND
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CONSTANT SKIN SECTION
IC 5-4-63
FORWARD
AFT
PAD-1
PAD-2
TYPICAL CIRCUMFERENTIAL WELD
SPOT
SEAM
Y
Q-1
X
Q-2
Y
Q-3
X
Q-4
Y
STA 219 D
AREA
E STA251 E
AREA
F STA284 F
AREA
G STA313 G
AREA
H STA344 H
AREA
I STA376 I
AREA
J STA408

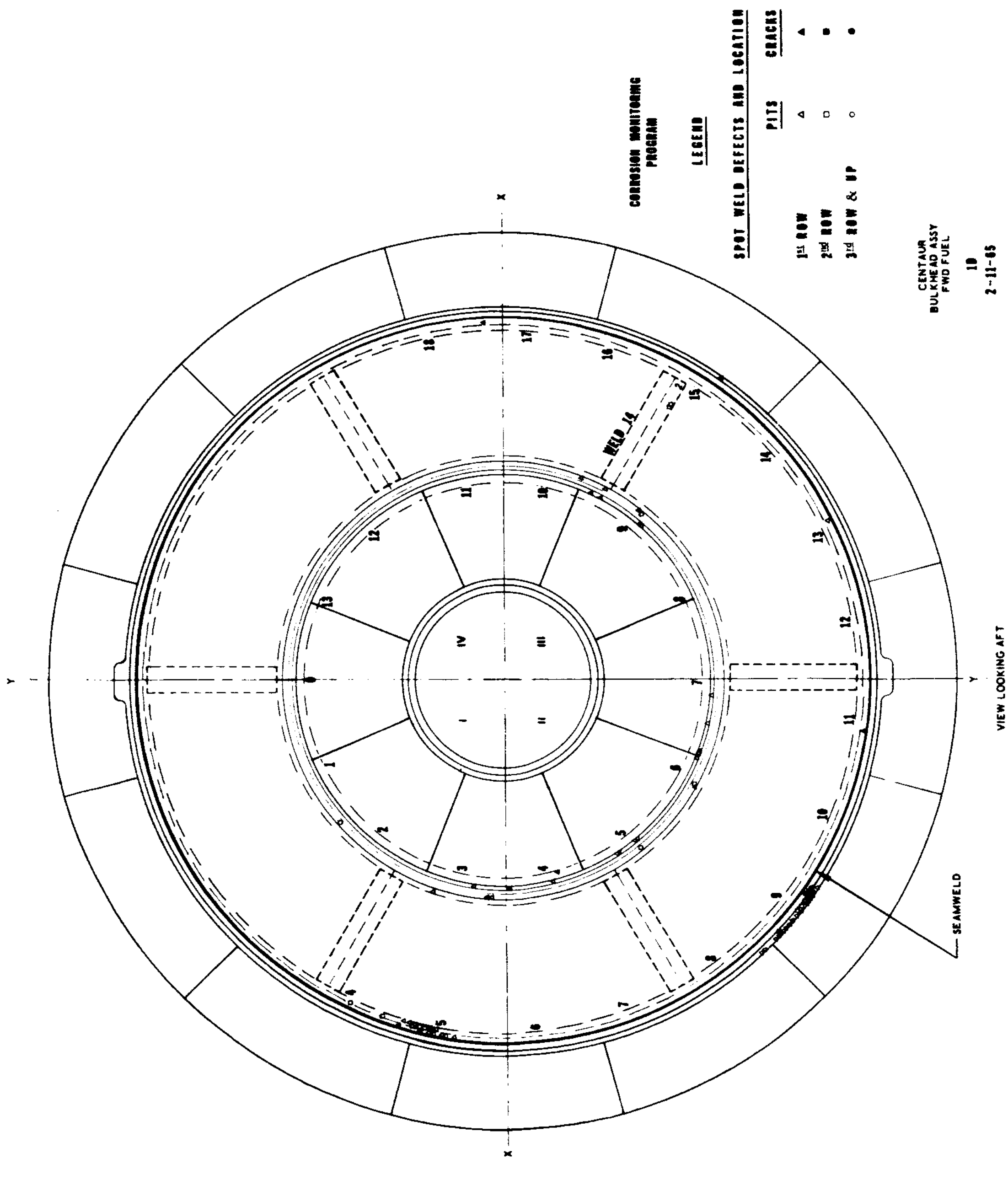

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
WELD ASSY
AFT BULKHEAD
1C
5-4-63
X
Y
I
II
III
IV
VIEW LOOKING FORWARD
AFT BULKHEAD
"A" THROUGH "C" TANKS

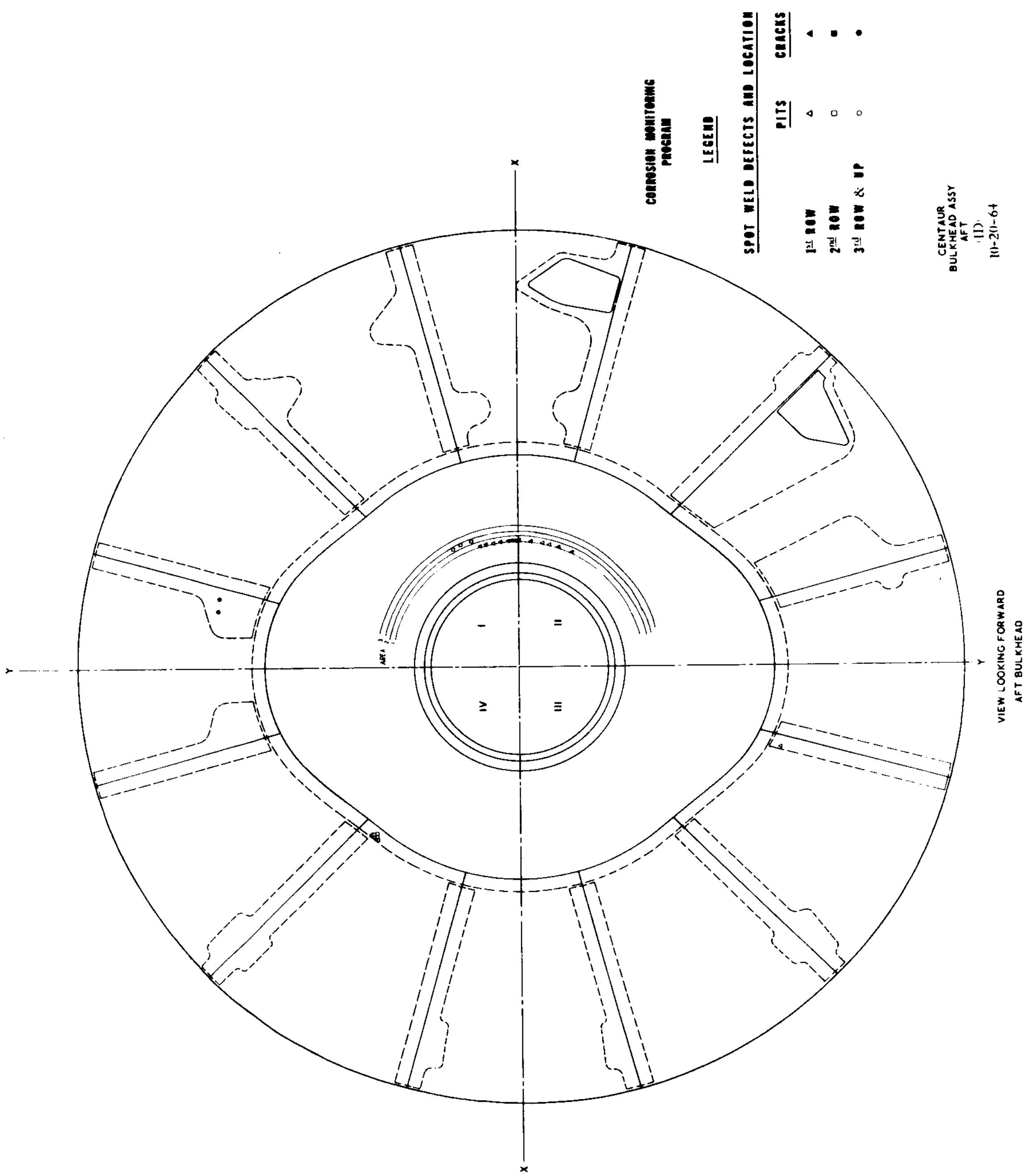

Y
Q-4
X
Q-3
Y
Q-2
X
Q-1
FORWARD
Y
STA 219 D
AREA
E STA 251 E
AREA
F STA 284 F
AREA
G STA 313 G
AREA
H STA 344 H
AREA
I STA 376 I
AREA
J STA 408
AFT
PAD-1
PAD-2
SPOT
SEAM
SPOT
TYPICAL CIRCUMFERENTIAL WELD
CONSTANT SKIN SECTION
3C 9-8-64
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP

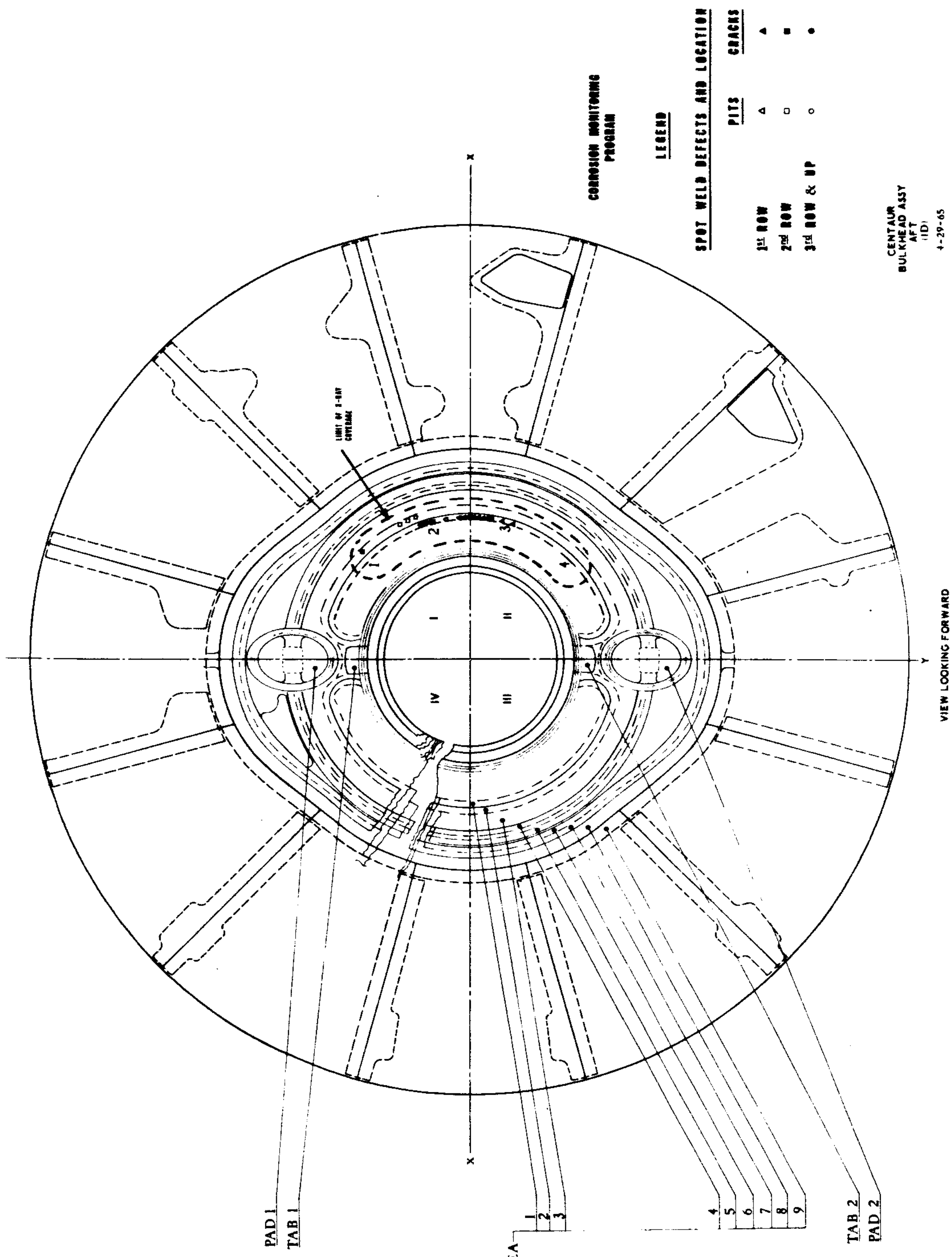

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
WELD ASSY
AFT BULKHEAD
(3C)
9-8-64
VIEW LOOKING FORWARD
AFT BULKHEAD
"A" THROUGH "C" TANKS
X
Y
I
II
III
IV

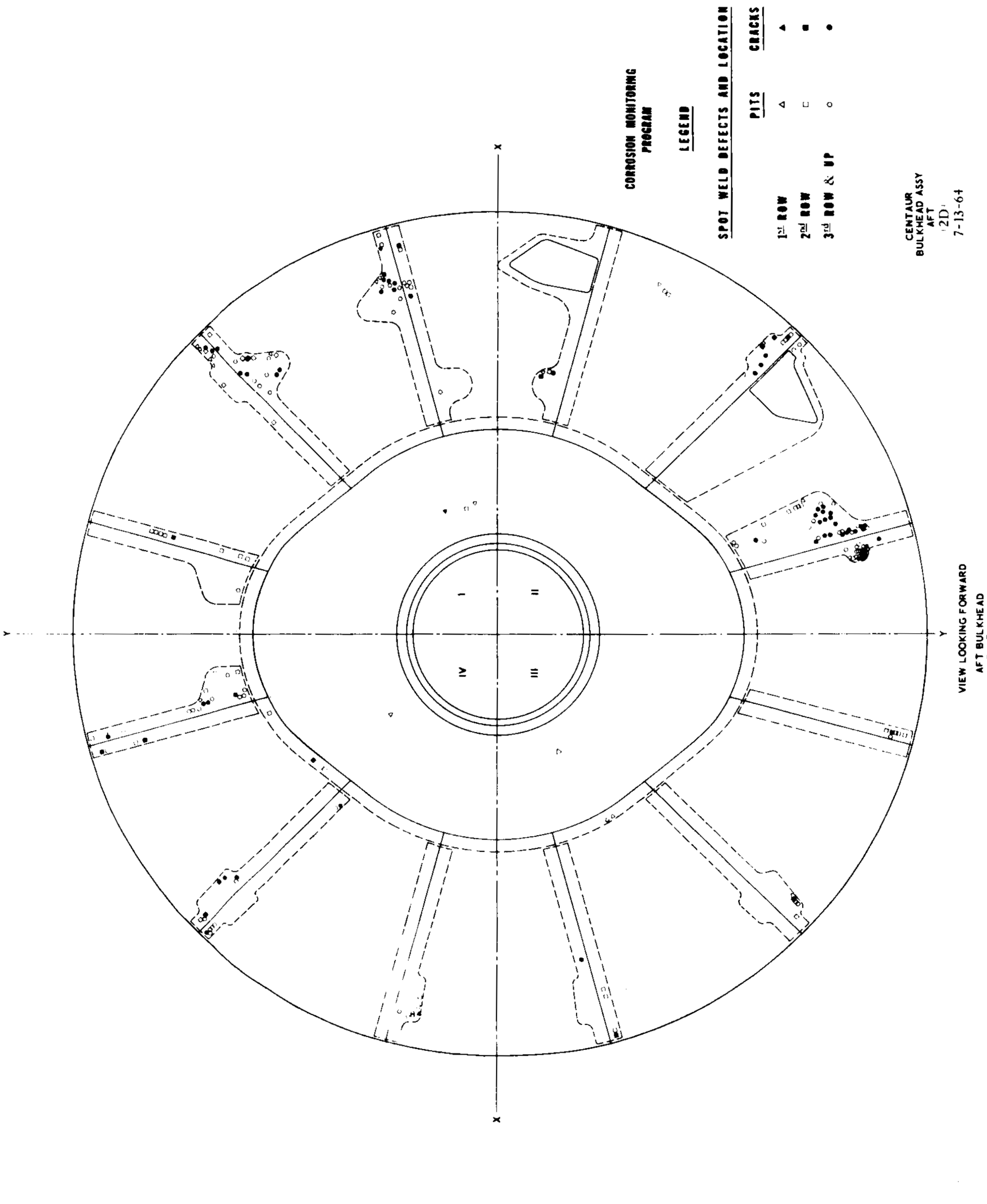

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR WELD ASSY APT BULKHEAD (6C) 10-28-64
LIMIT OF X-RAY COVERAGE
X
Y
I
II
III
IV
VIEW LOOKING FORWARD AFT BULKHEAD "A" THROUGH "C" TANKS

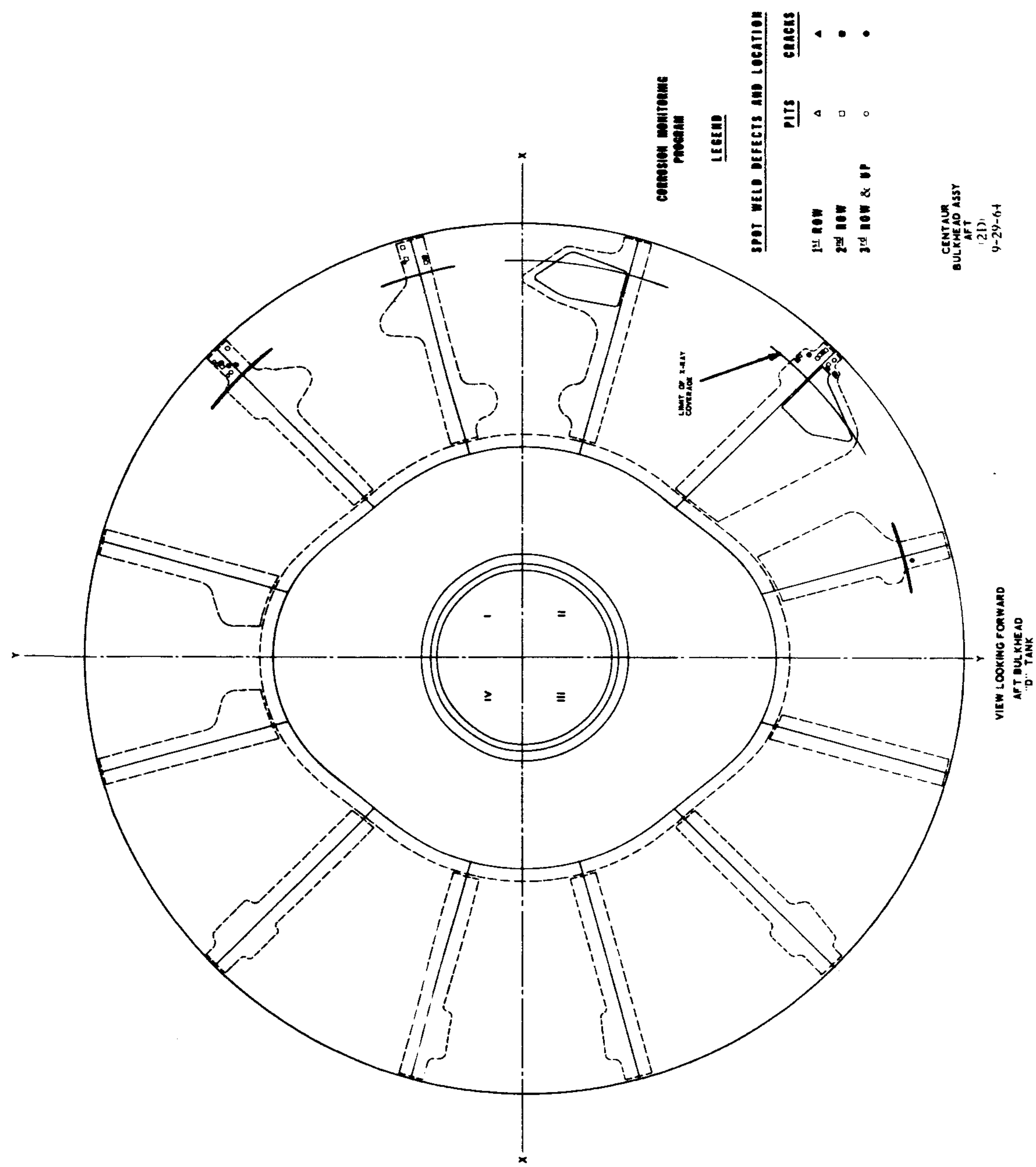

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
(D)
8-6-64
VIEW LOOKING AFT
D TANK
SEAMWELD
X
Y

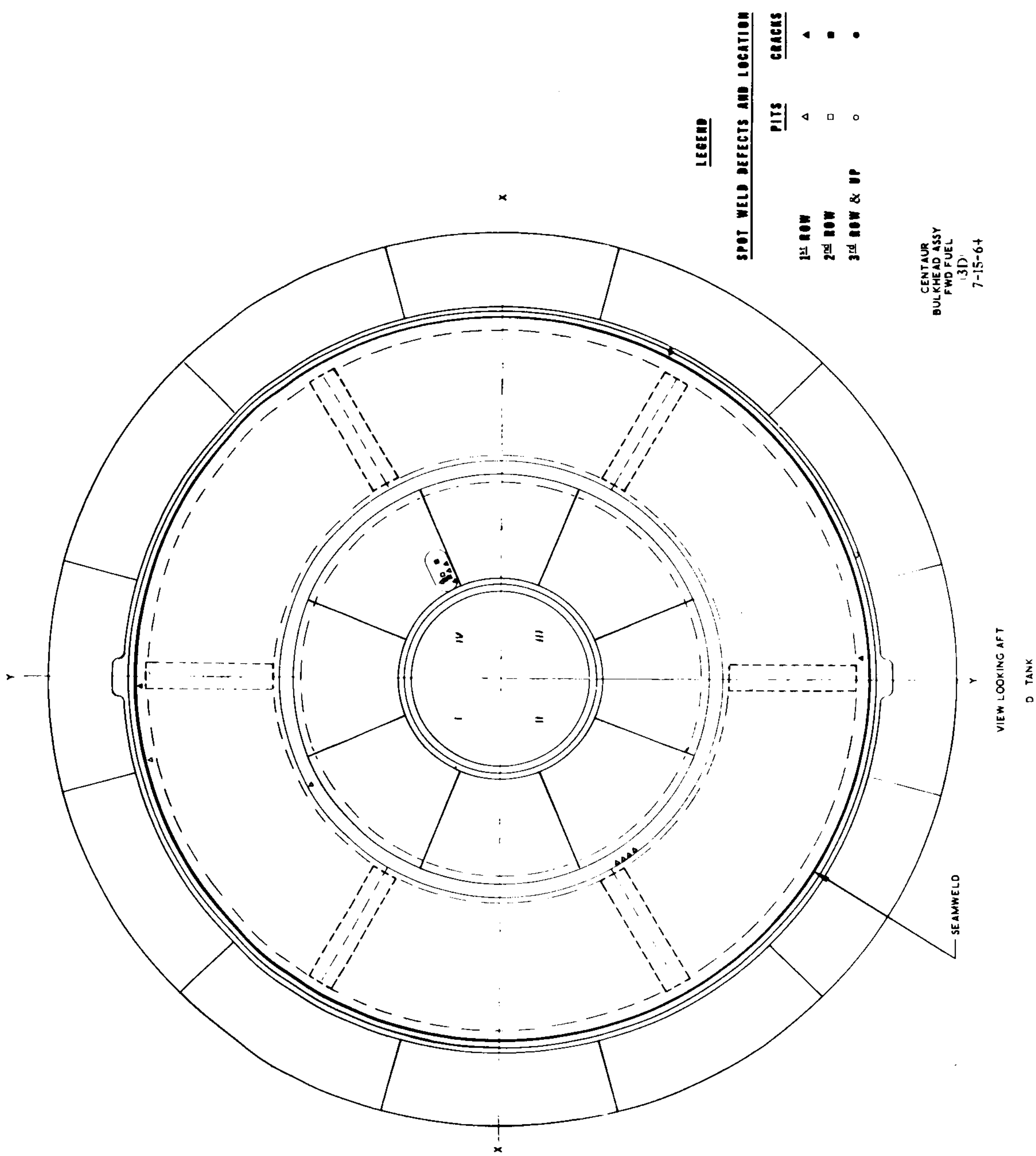

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
1D
2-11-65
VIEW LOOKING AFT
"D" TANK
SEAMWELD
WELD 14

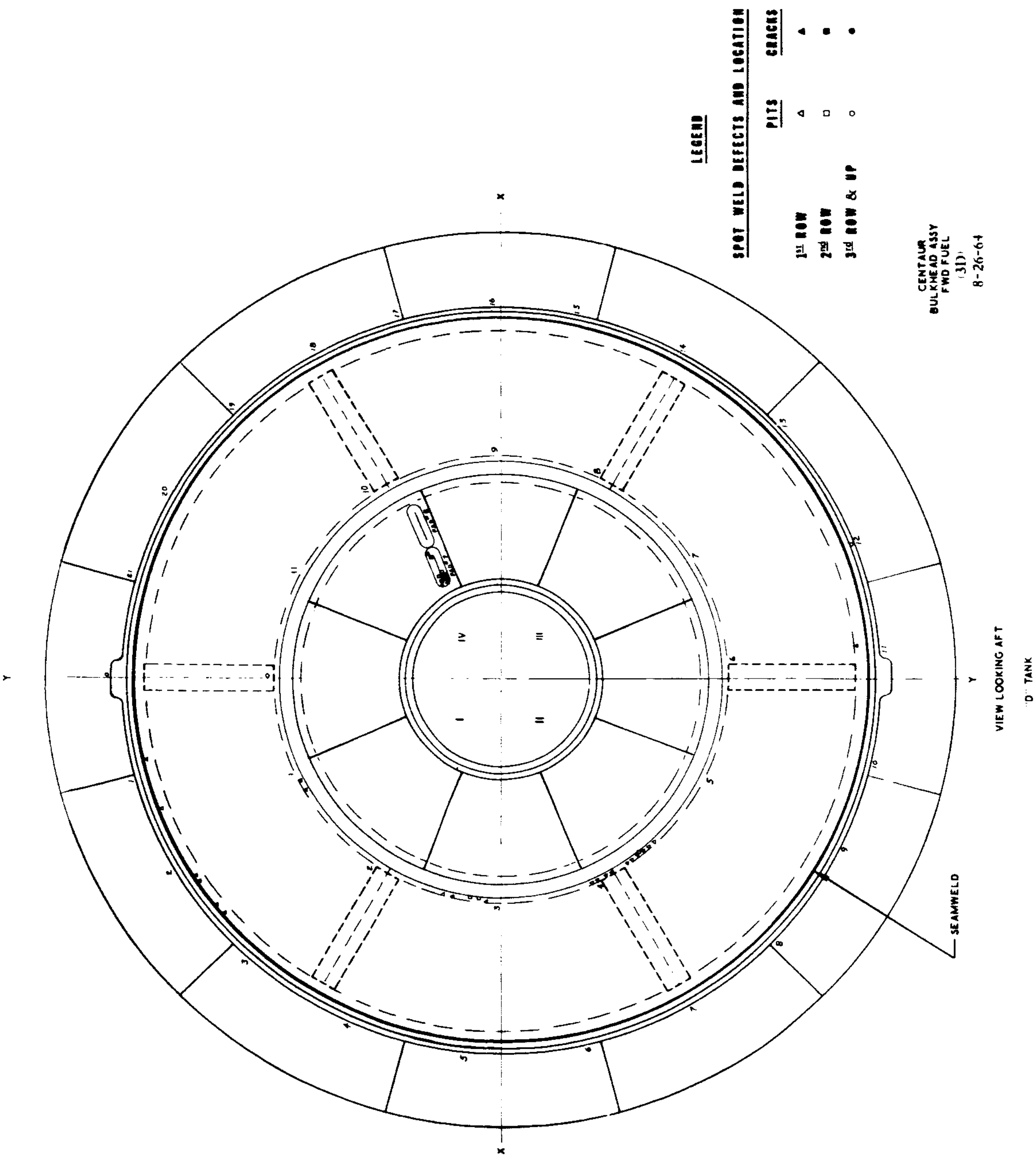

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR BULKHEAD ASSY AFT
(1)
10-20-64
VIEW LOOKING FORWARD AFT BULKHEAD D TANK
X
Y
I
II
III
IV

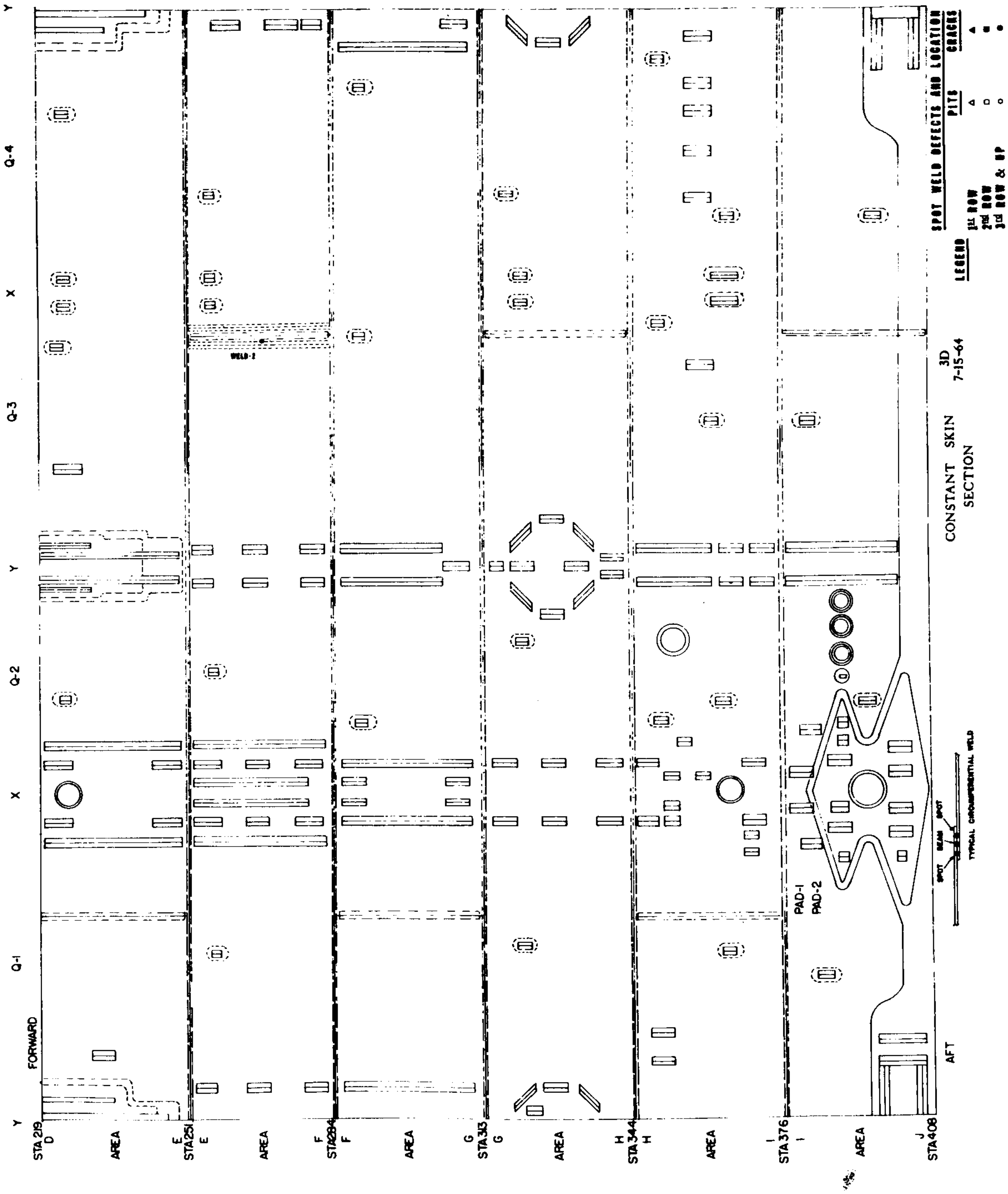

CORROSION MONITORING
PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
LIMIT OF X-RAY COVERAGE
PAD 1
TAB 1
AREA
1
2
3
4
5
6
7
8
9
TAB 2
PAD 2
X
Y
I
II
III
IV
VIEW LOOKING FORWARD
AFT BULKHEAD
"D" TANK
CENTAUR
BULKHEAD ASSY
AFT
(ID)
4-29-65

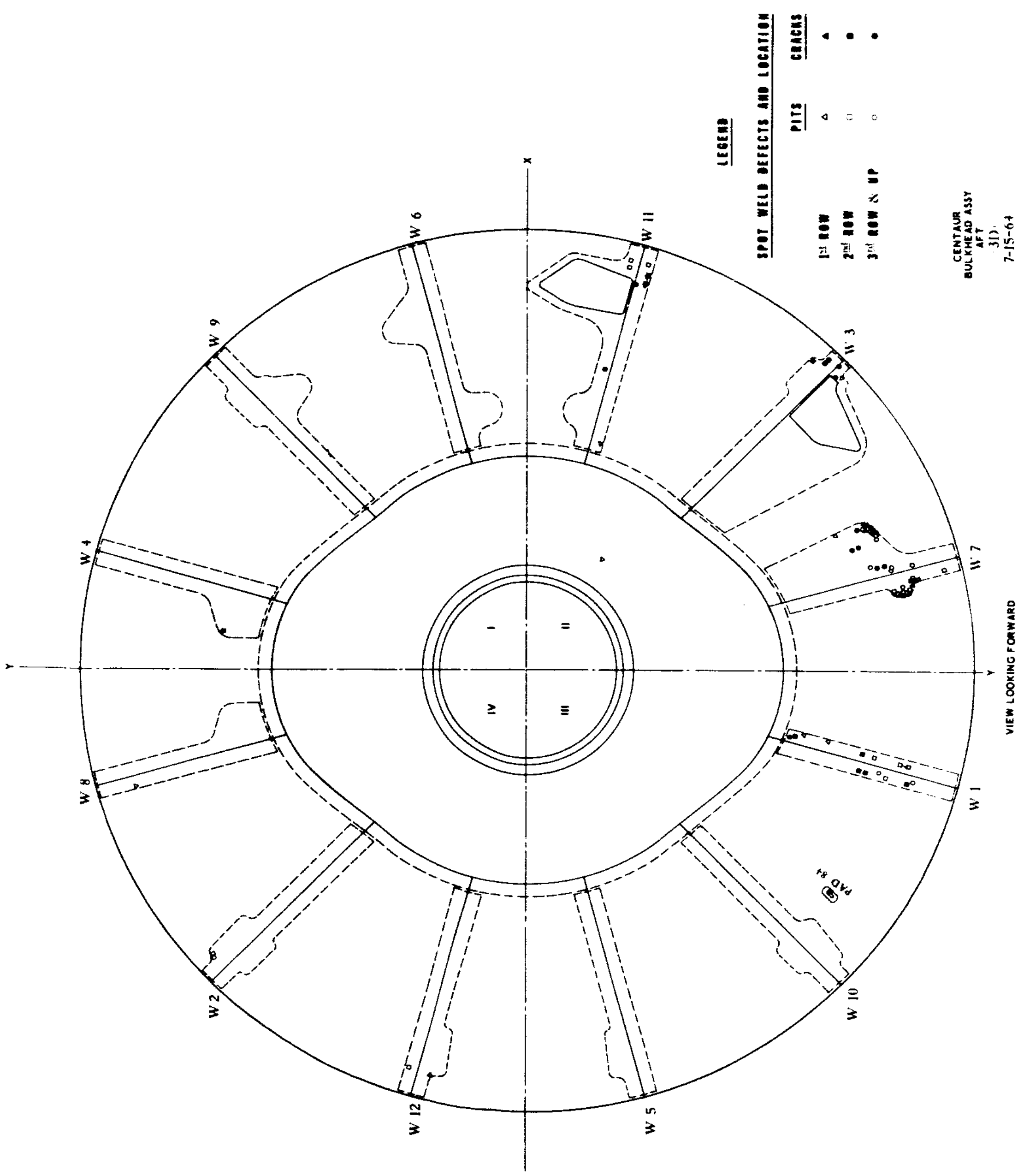

CORROSION MONITORNG PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR BULKHEAD ASSY AFT (2D) 7-13-64
VIEW LOOKING FORWARD AFT BULKHEAD D TANK
X
X
Y
Y
I
II
III
IV

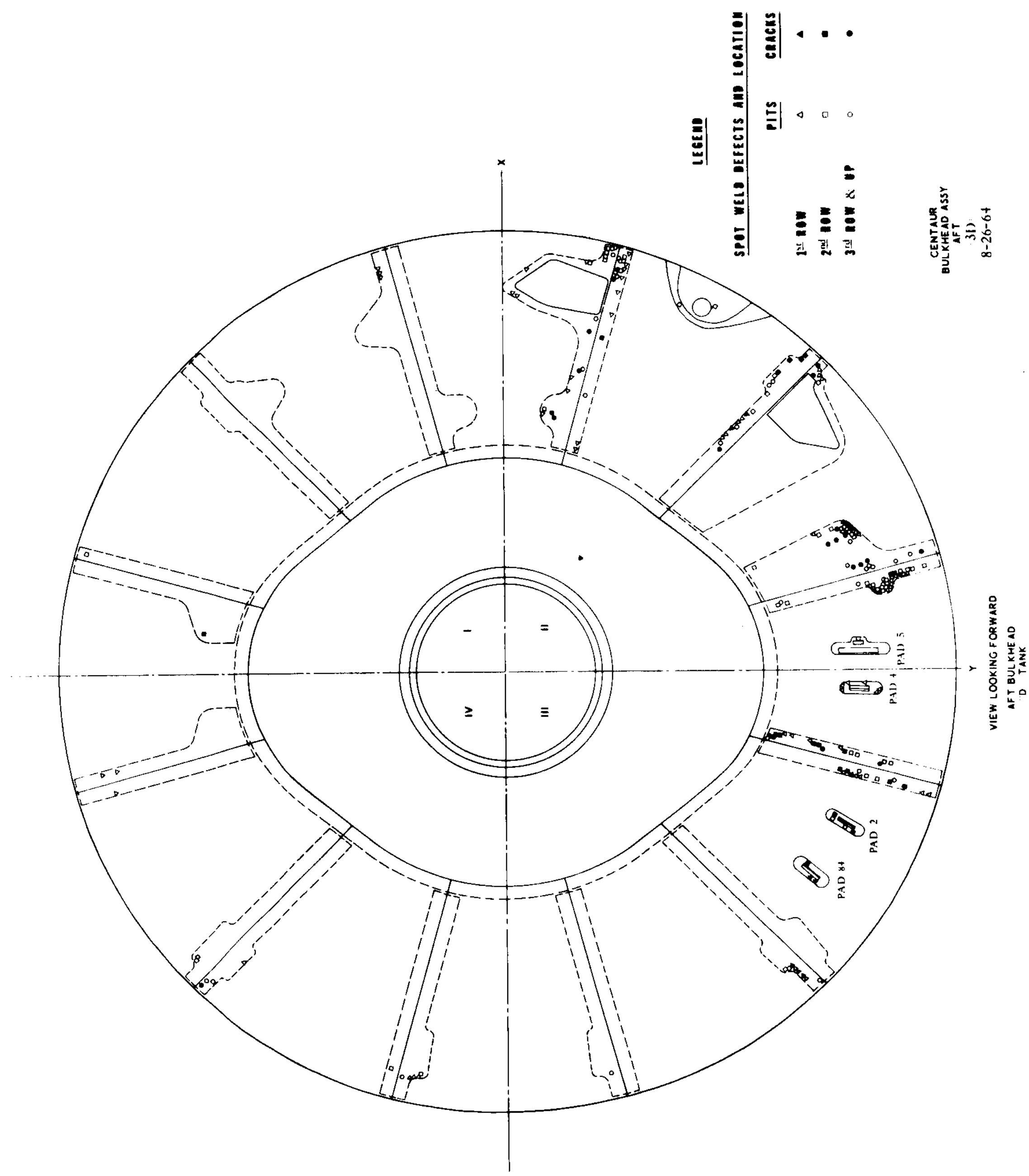

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR BULKHEAD ASSY AFT (21) 9-29-64
LIMIT OF X-RAY COVERAGE
VIEW LOOKING FORWARD AFT BULKHEAD "D" TANK
X
Y
I
II
III
IV

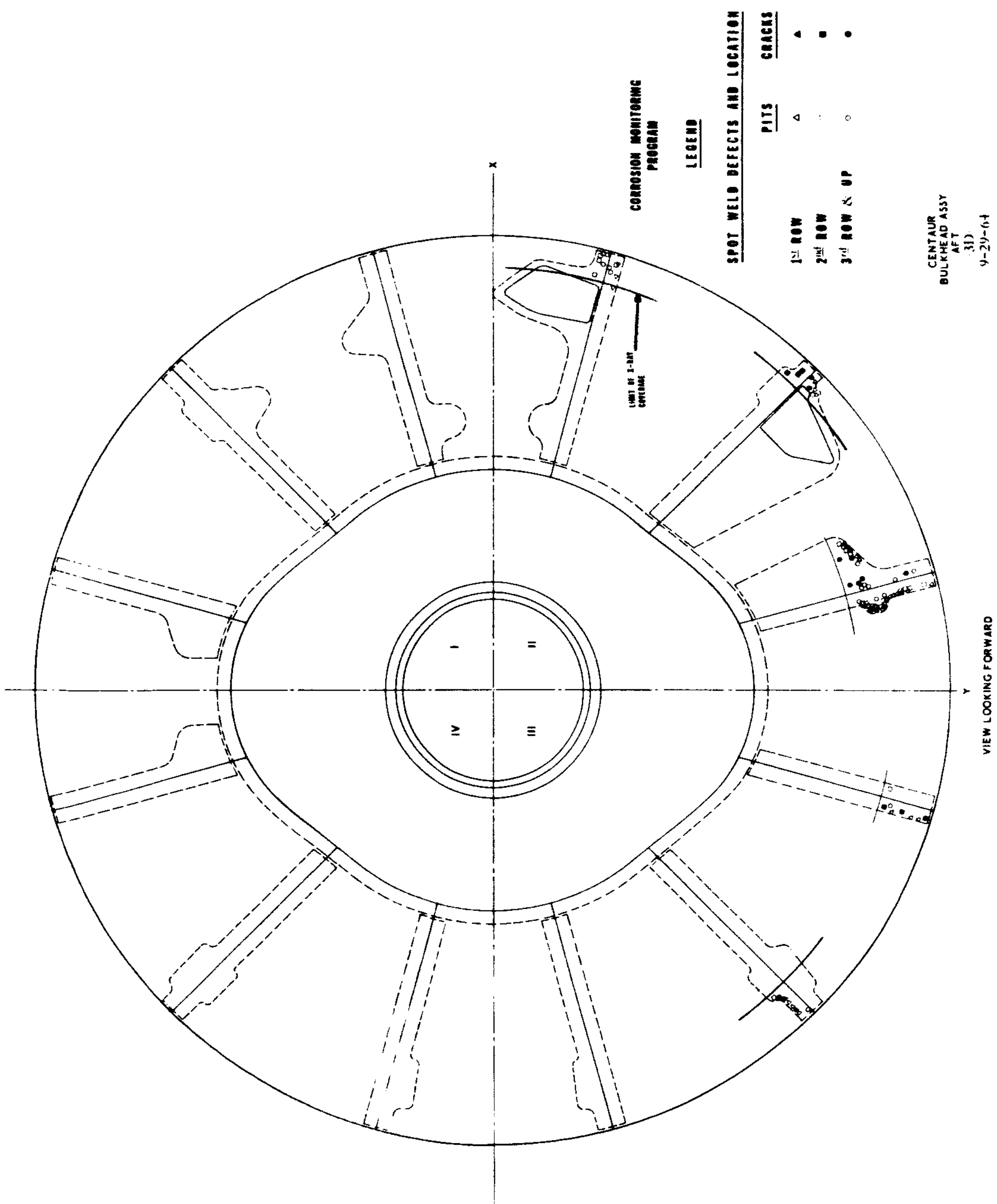

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
(3D)
7-15-64
VIEW LOOKING AFT
D TANK
SEAMWELD
X
Y
I
II
III
IV

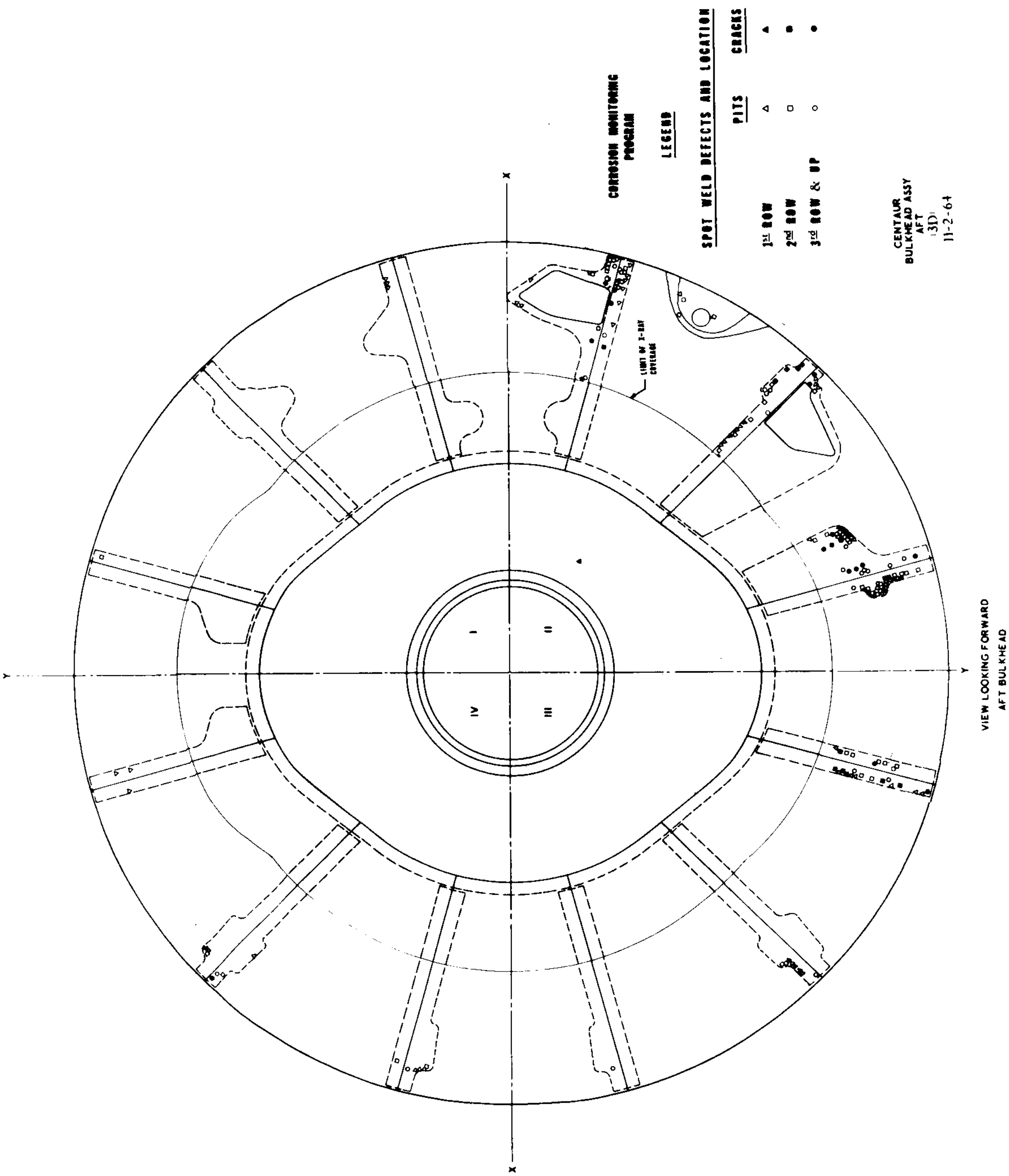

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
(31)
8-26-64
VIEW LOOKING AFT
'D' TANK
SEAMWELD

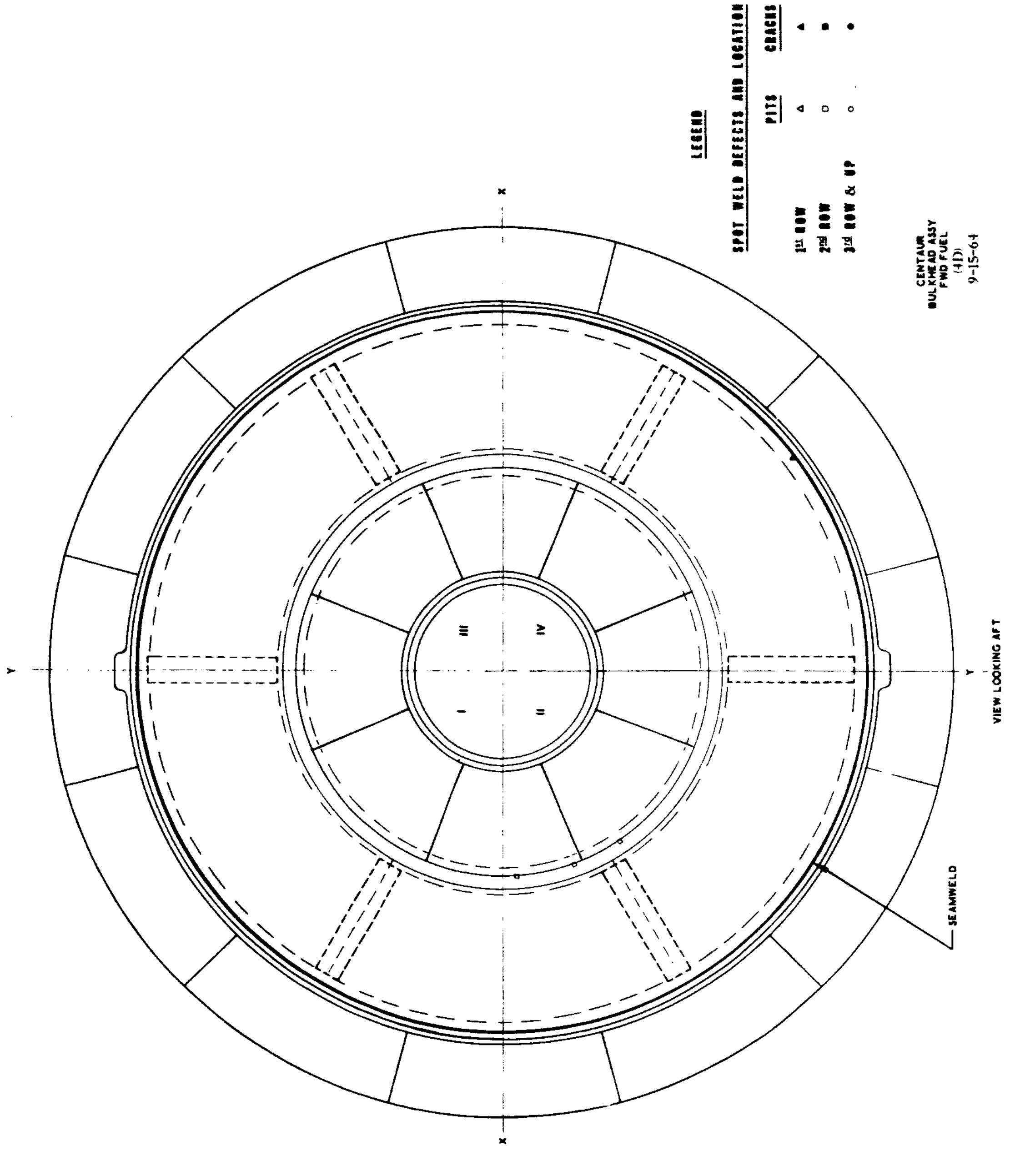

Y
Q-4
X
Q-3
Y
Q-2
X
Q-1
FORWARD
Y
STA 219 D
AREA
E STA 251 E
AREA
F STA 284 F
AREA
G STA 313 G
AREA
H STA 344 H
AREA
I STA 376 I
AREA
J STA 408
AFT
PAD-1
PAD-2
CONSTANT SKIN SECTION
3D 7-15-64
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP

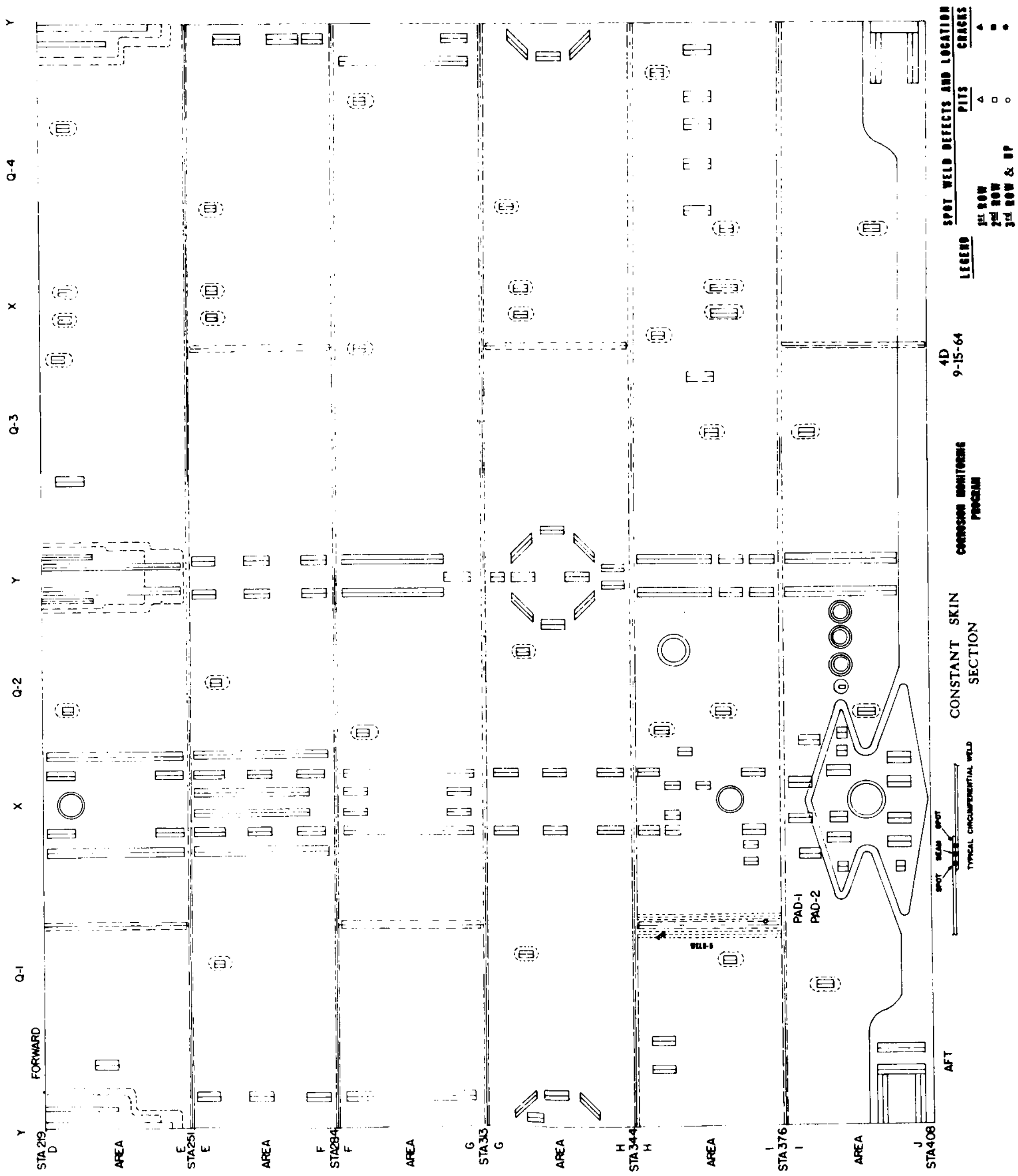

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
7-15-64
VIEW LOOKING FORWARD
AFT BULKHEAD
PAD 84
W 1
W 2
W 3
W 4
W 5
W 6
W 7
W 8
W 9
W 10
W 11
W 12
I
II
III
IV
X
Y

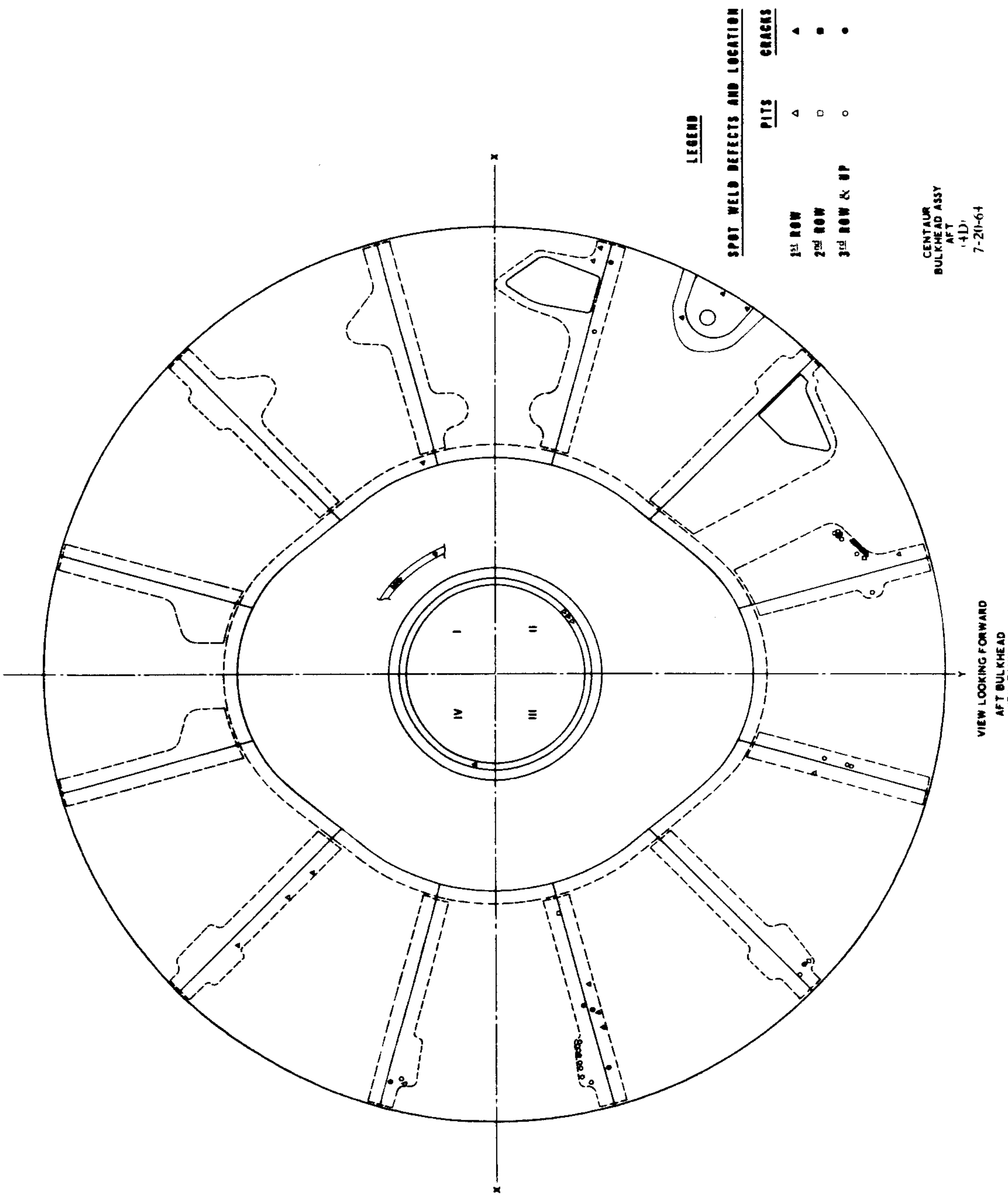

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
8-26-64
VIEW LOOKING FORWARD
AFT BULKHEAD
PAD 4
PAD 2
PAD 84
X
Y
I
II
III
IV

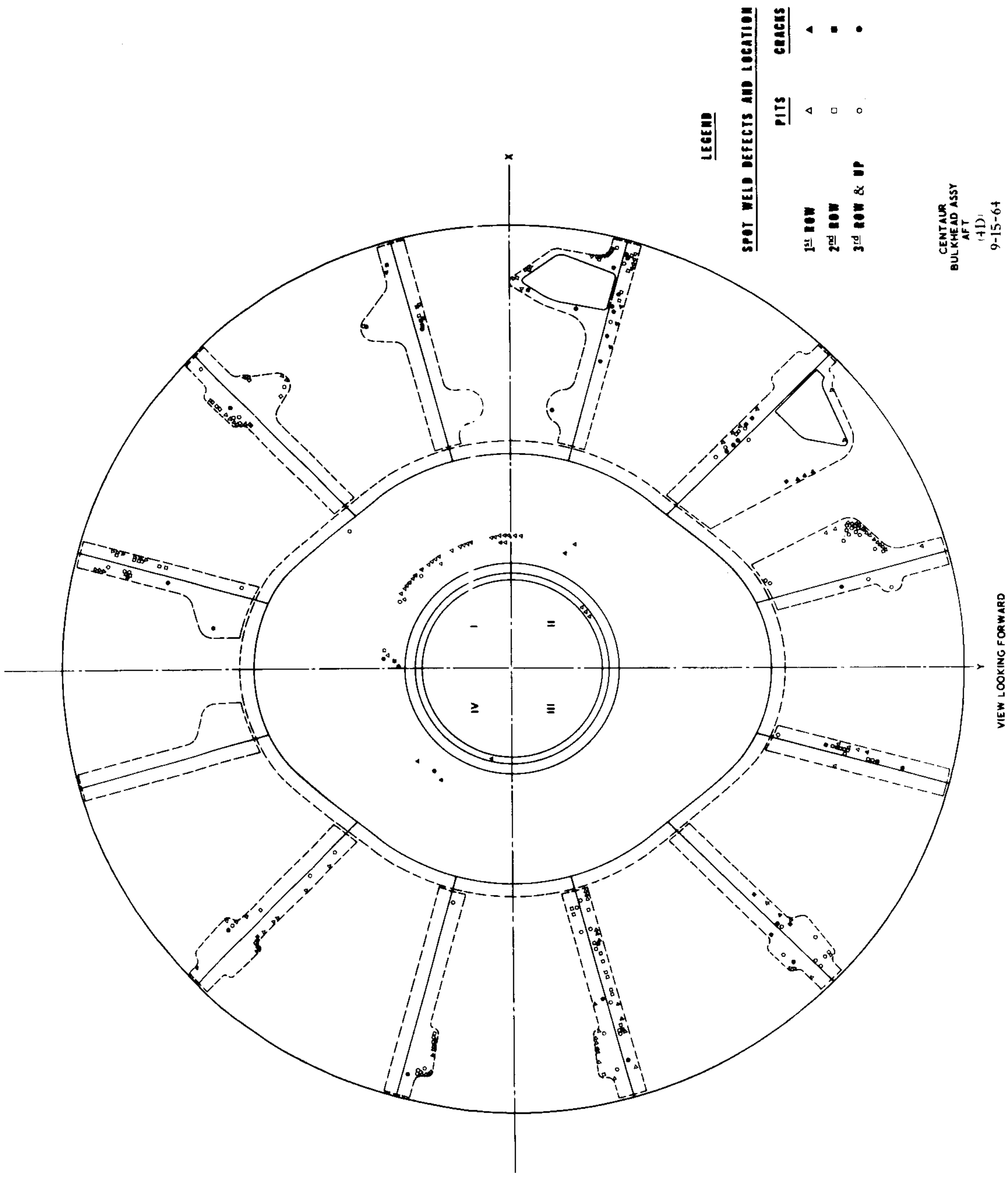

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
9-29-64
VIEW LOOKING FORWARD
AFT BULKHEAD
TANK
X
Y
I
II
III
IV

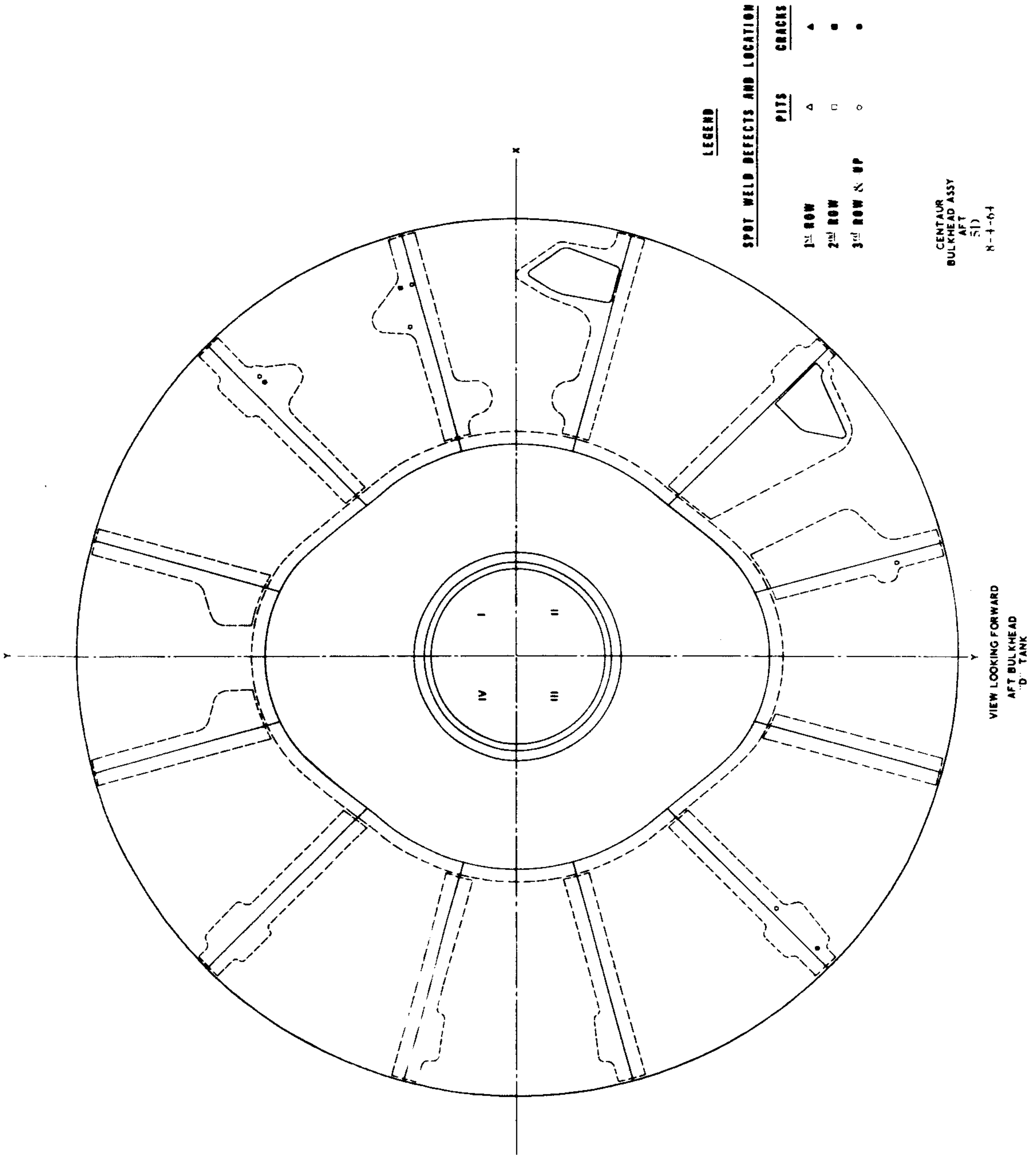

CORROSION MONITORING PROGRAM
LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
(3D)
11-2-64
LIMIT OF X-RAY COVERAGE
VIEW LOOKING FORWARD
AFT BULKHEAD
TANK
I
II
III
IV
X
Y

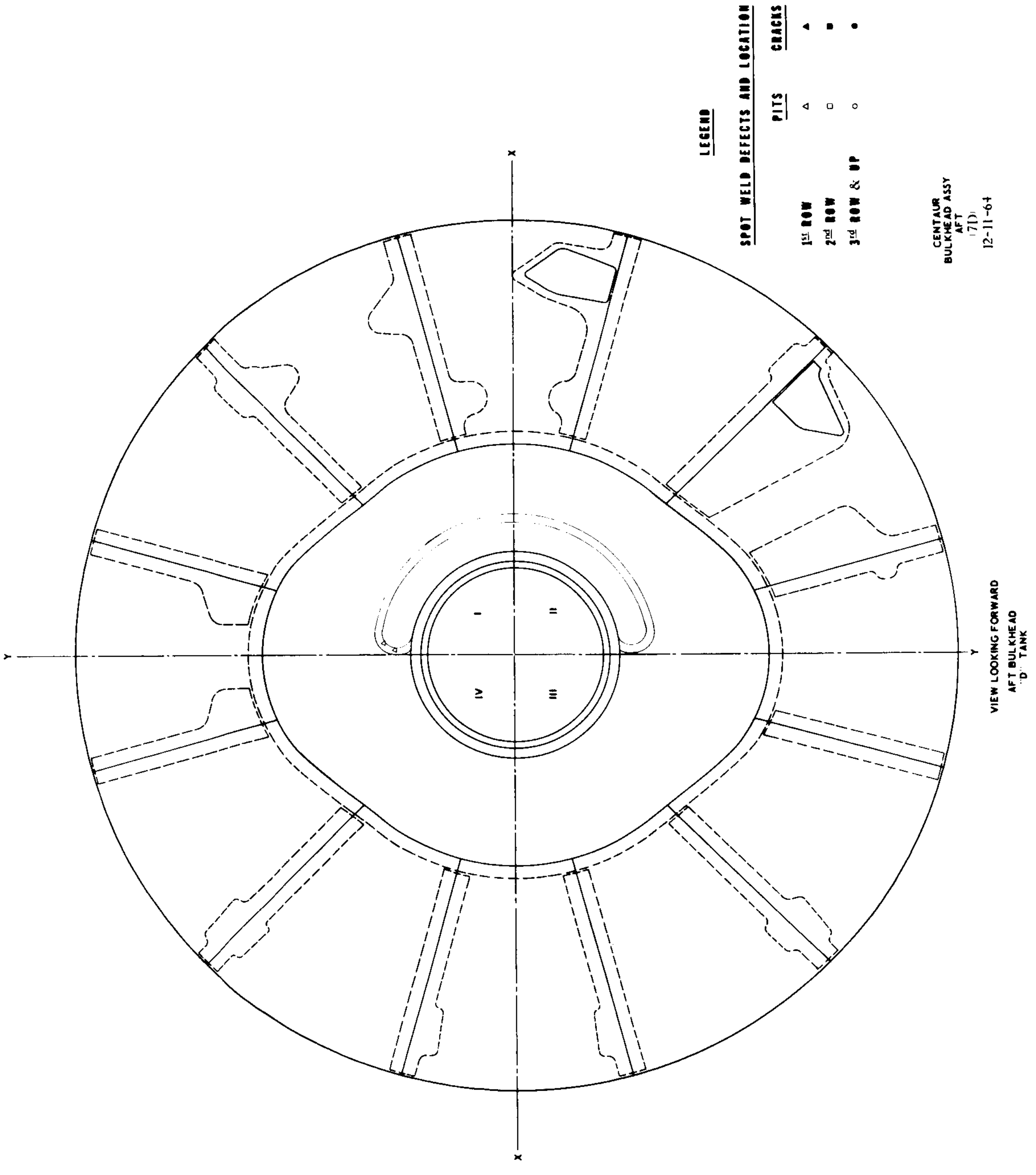

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
FWD FUEL
(4D)
9-15-64
VIEW LOOKING AFT
'D' TANK
SEAMWELD

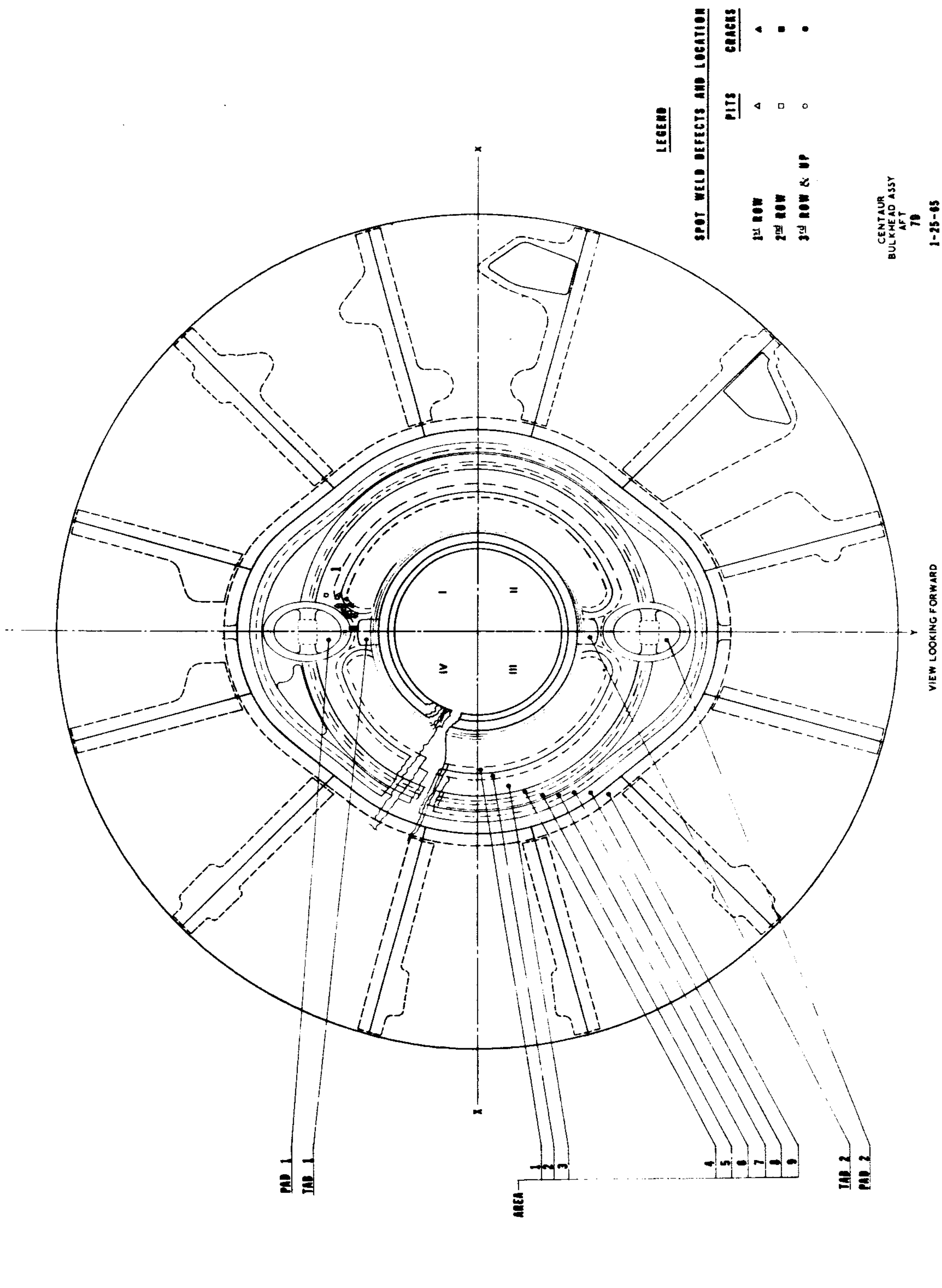

SPOT WELD DEFECTS AND LOCATION
LEGEND
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
4D
9-15-64
CORROSION MONITORING PROGRAM
CONSTANT SKIN SECTION
TYPICAL CIRCUMFERENTIAL WELD
SPOT
SEAM
SPOT
FORWARD
AFT
PAD-1
PAD-2
Y
Q-1
X
Q-2
Y
Q-3
X
Q-4
Y
STA 219 D
AREA
E STA 251 E
AREA
F STA 284 F
AREA
G STA 313 G
AREA
H STA 344 H
AREA
I STA 376 I
AREA
J STA 408

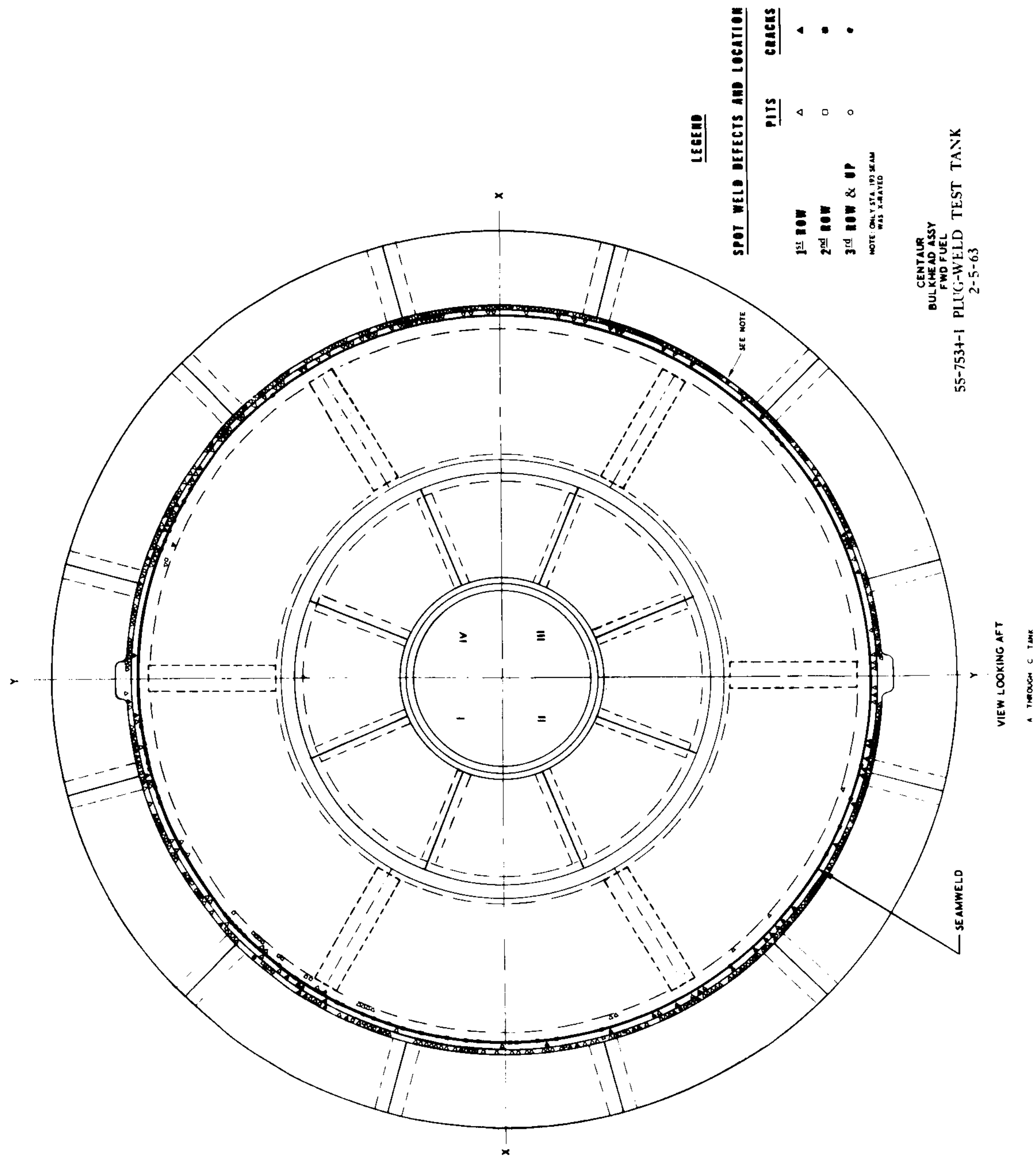

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
(-D)
7-20-64
VIEW LOOKING FORWARD
AFT BULKHEAD
"D" TANK
X
Y
I
II
III
IV


LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
(4D)
9-15-64
VIEW LOOKING FORWARD
AFT BULKHEAD
O TANK
X
Y
I
II
III
IV


LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
5D
8-4-64
VIEW LOOKING FORWARD
AFT BULKHEAD
"D" TANK
X
Y
I
II
III
IV


LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
(7D)
12-11-64
VIEW LOOKING FORWARD
AFT BULKHEAD
"D" TANK
X
Y
I
II
III
IV


LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
CENTAUR
BULKHEAD ASSY
AFT
7D
1-25-65
VIEW LOOKING FORWARD
AFT BULKHEAD
"D" TANK
I
II
III
IV
X
Y
PAD 1
TAB 1
AREA
1
2
3
4
5
6
7
8
9
TAB 2
PAD 2

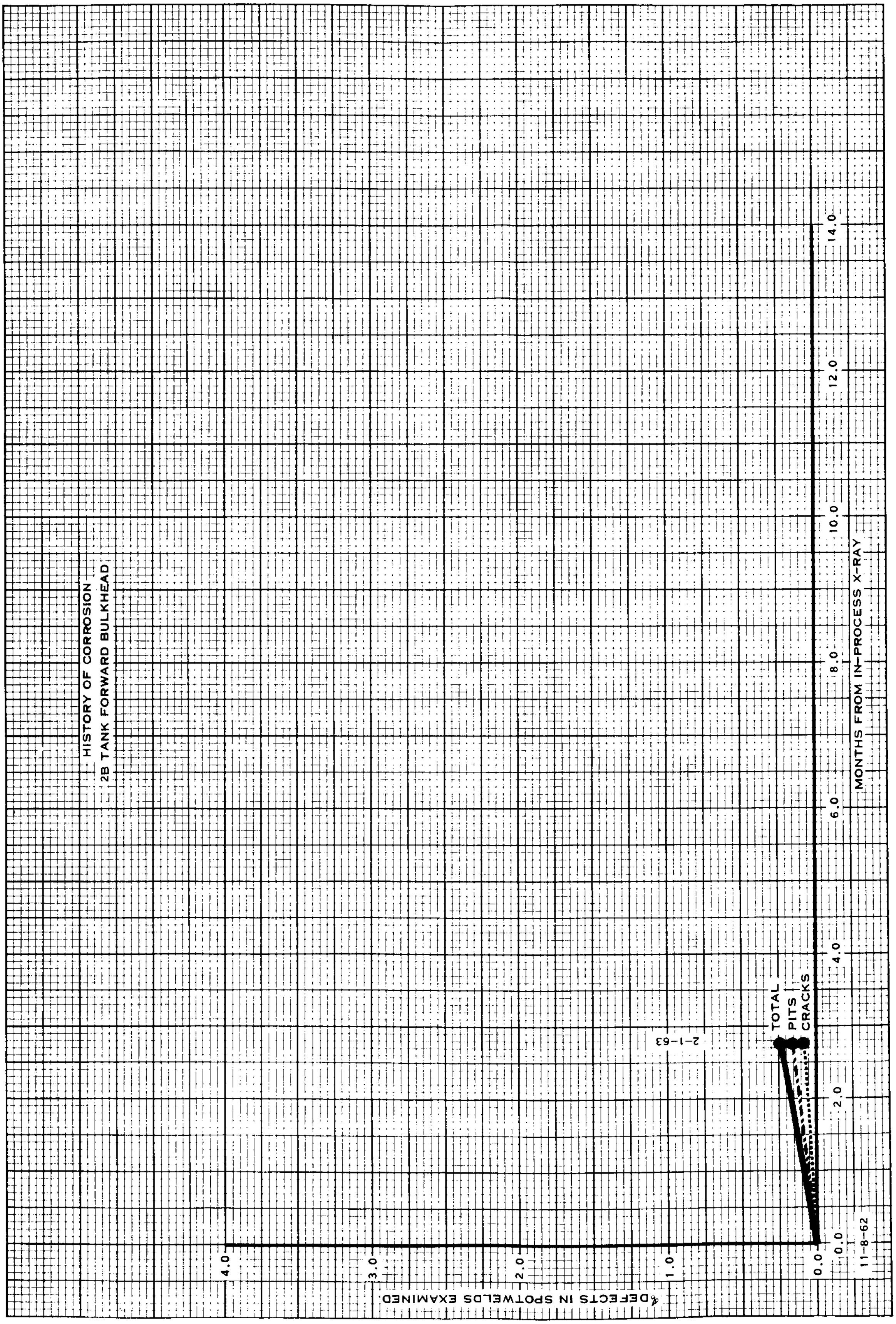

LEGEND
SPOT WELD DEFECTS AND LOCATION
PITS
CRACKS
1st ROW
2nd ROW
3rd ROW & UP
NOTE: ONLY STA. 193 SEAM WAS X-RAYED
SEE NOTE
CENTAUR
BULKHEAD ASSY
FWD FUEL
55-7534-1 PLUG-WELD TEST TANK
2-5-63
X
Y
IV
III
I
II
SEAMWELD
VIEW LOOKING AFT
A THROUGH C TANK

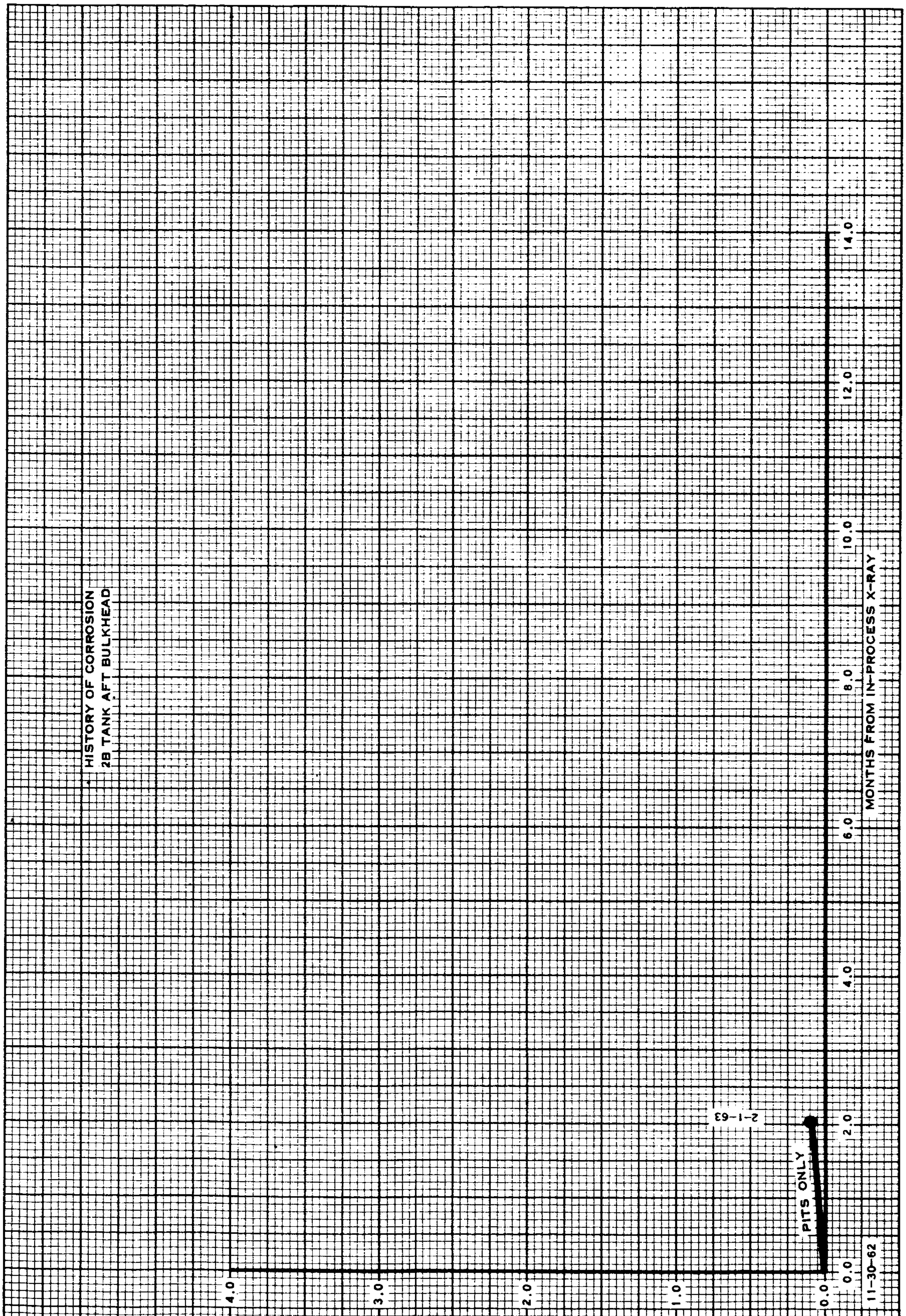
APPENDIX D

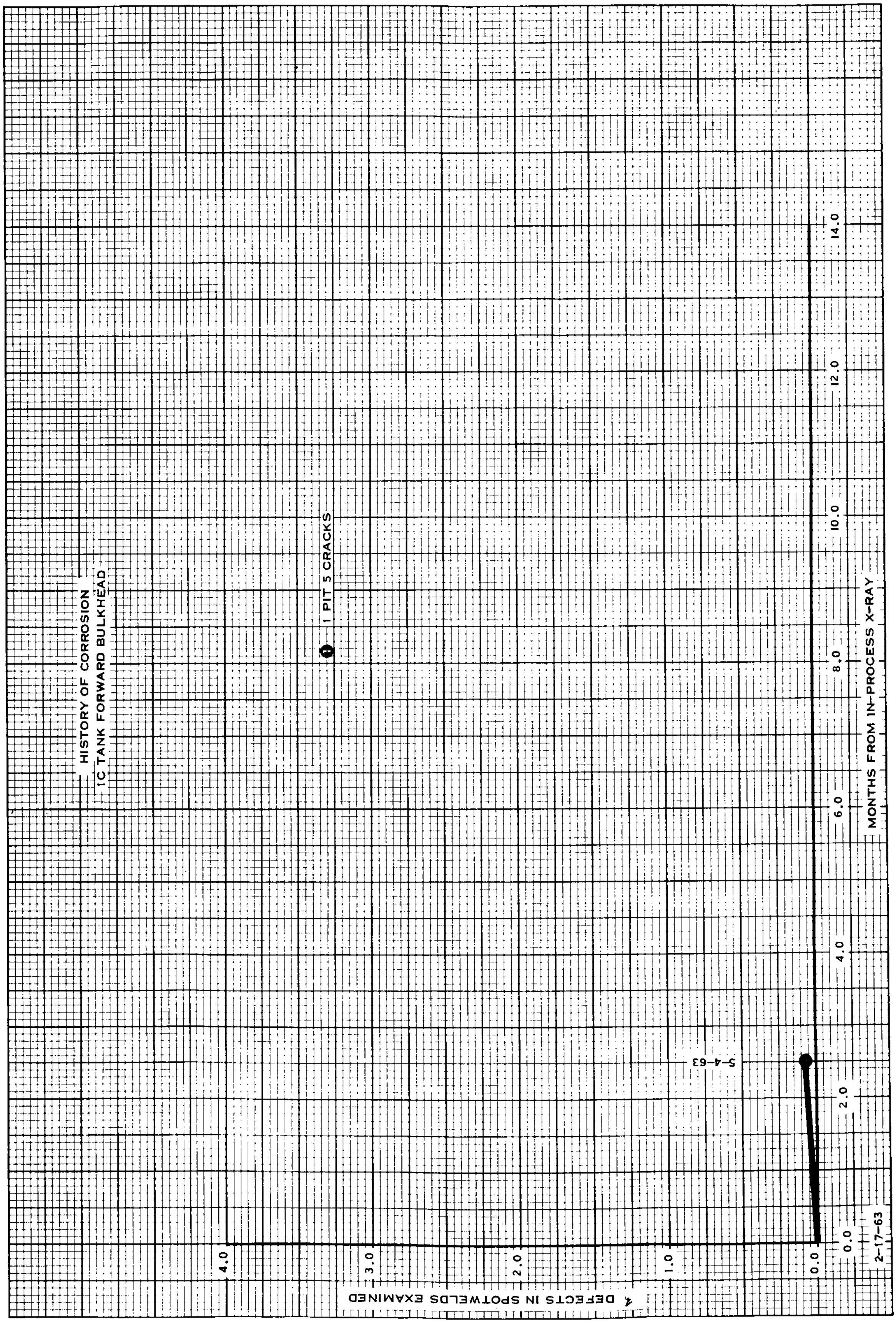
D-1.1 CORROSION PLOTS

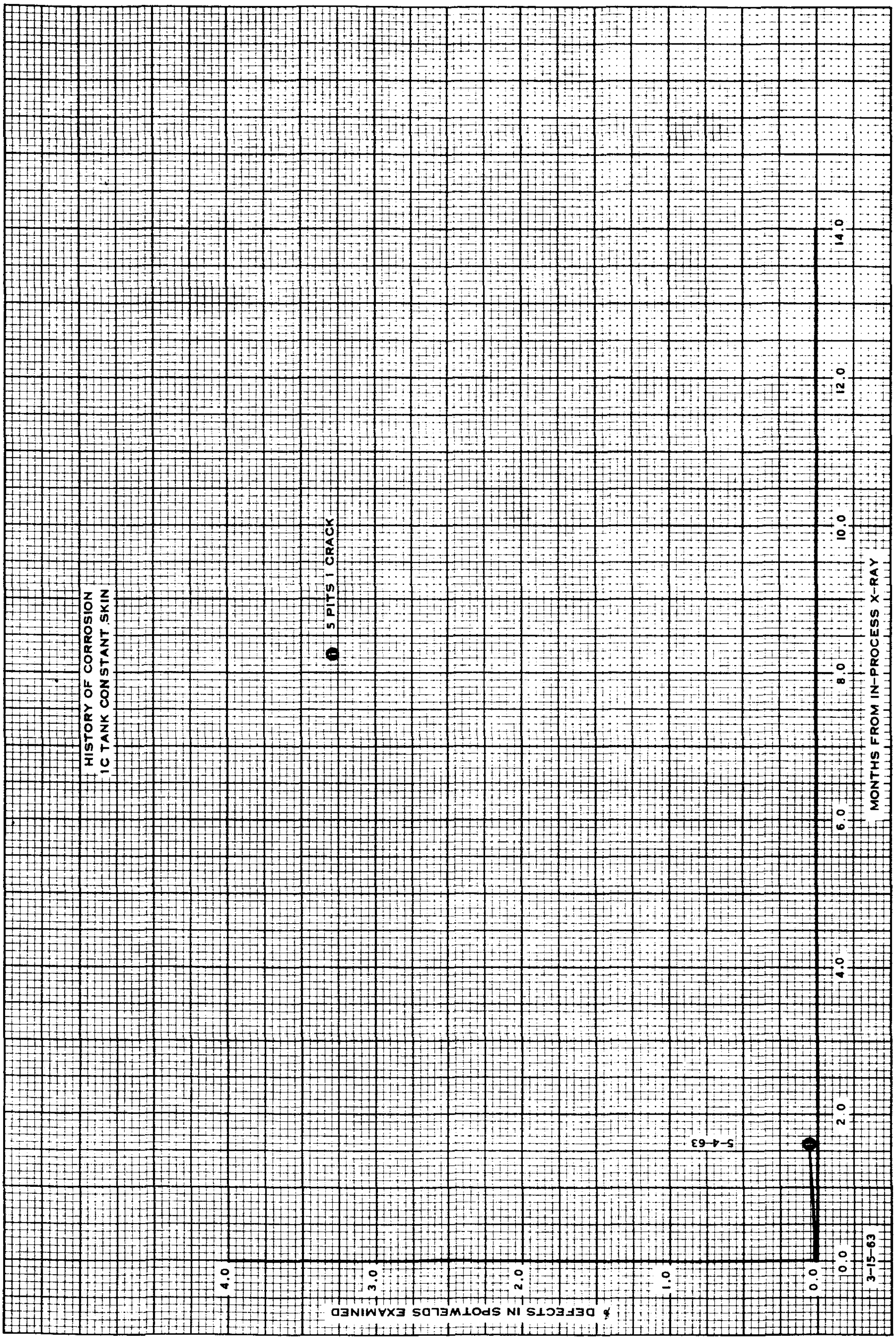
D-1.1.1 CORROSION VERSUS TIME. Corrosion Plots herein presented are shown for X-ray inspections except where only a few defects were noted. During the corrosion monitoring program, only selected areas of the bulkhead were accessible for X-ray since the tanks were on the production line and sealed to maintain LO_2 cleanness and pressurization. Equipment mounted on the tank also interferred with X-ray equipment. The areas monitored were usually areas of heaviest corrosion, therefore the corrosion monitoring program plots generally show a higher percentage of defects than the plots of the 100 percent X-ray examinations.

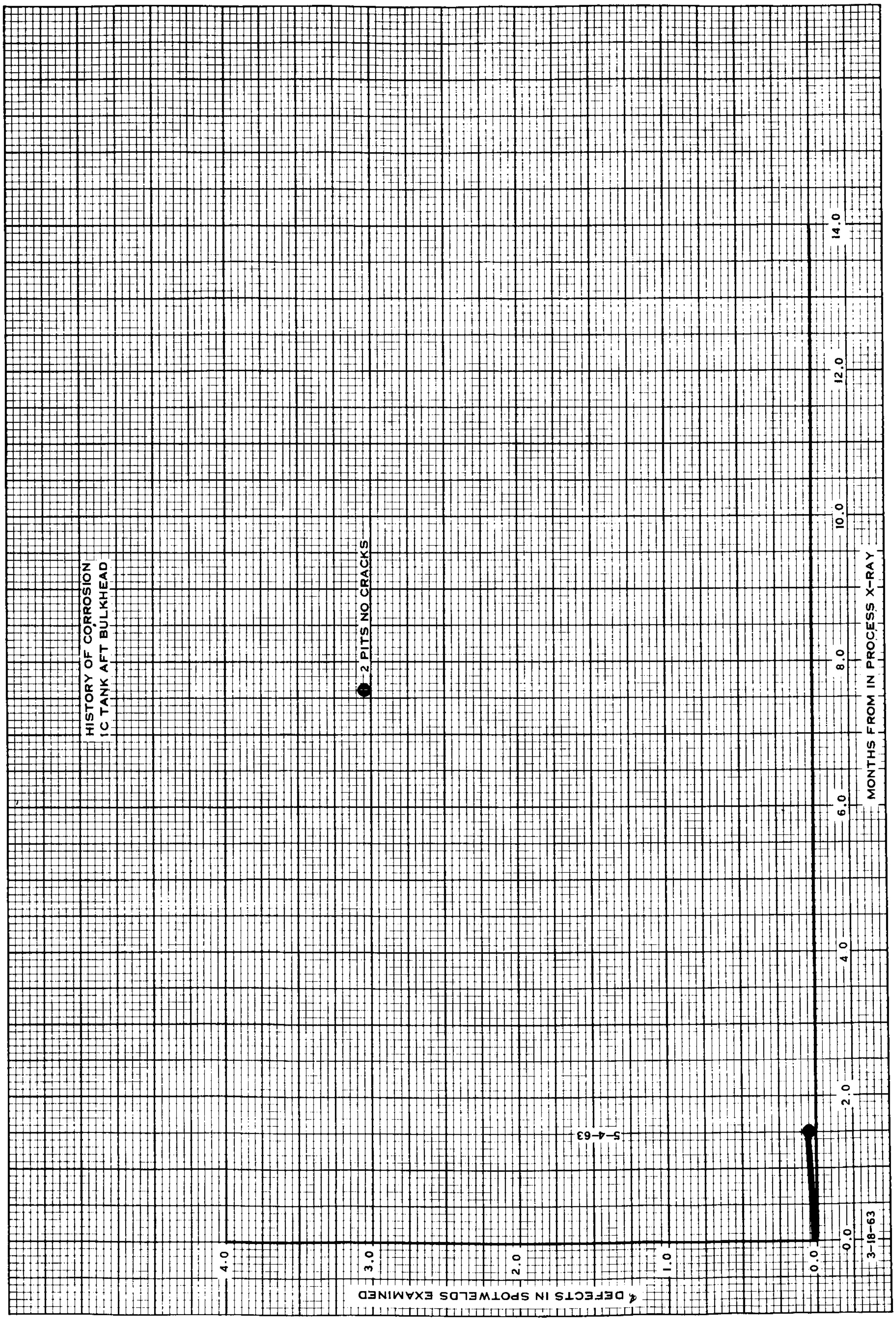
Also included are crack propagation plots which show crack lengths for individual spotweld as they were monitored from one X-ray examination to another.

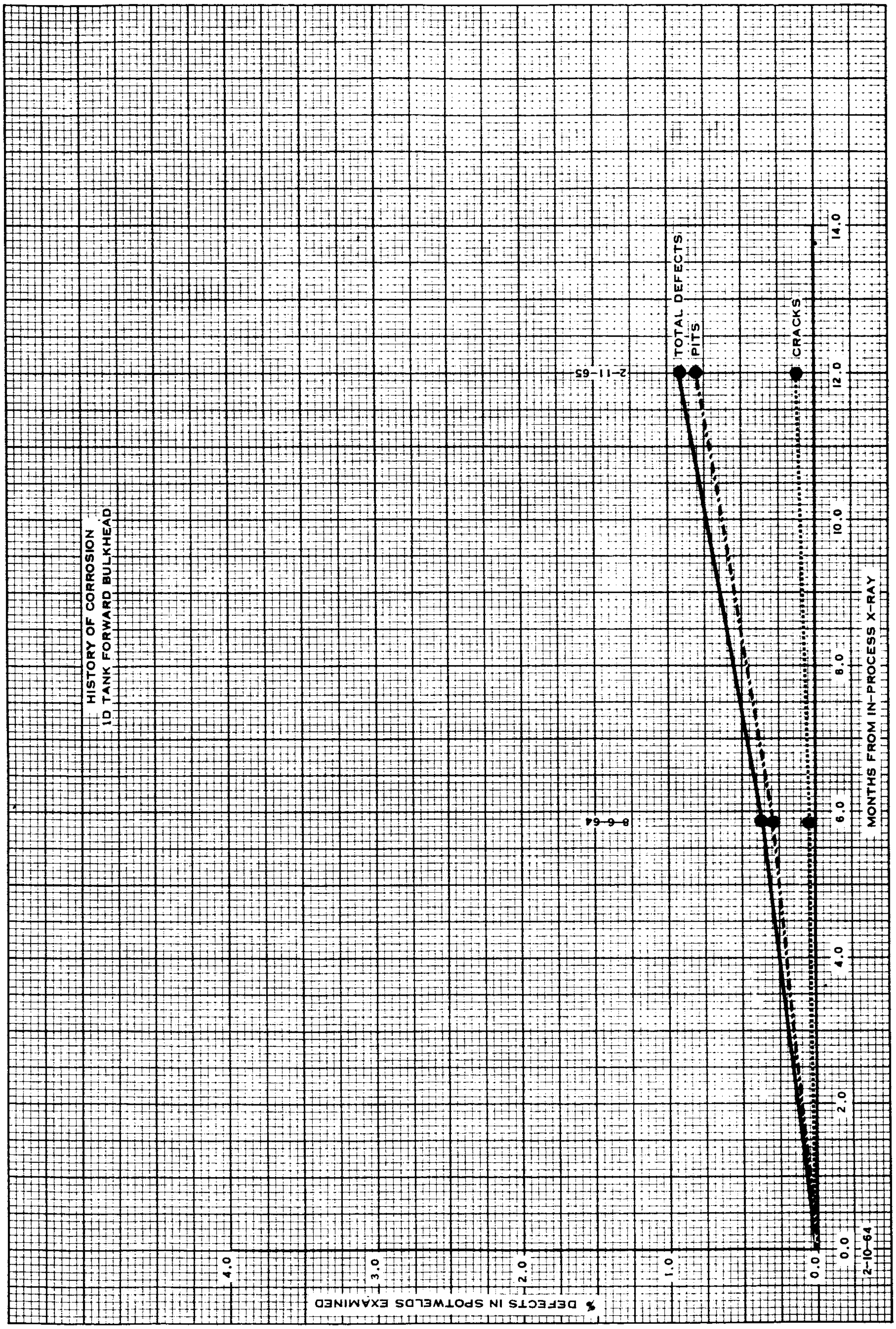

HISTORY OF CORROSION
2B TANK FORWARD BULKHEAD
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0
TOTAL
PITS
CRACKS
2-1-63
11-8-62

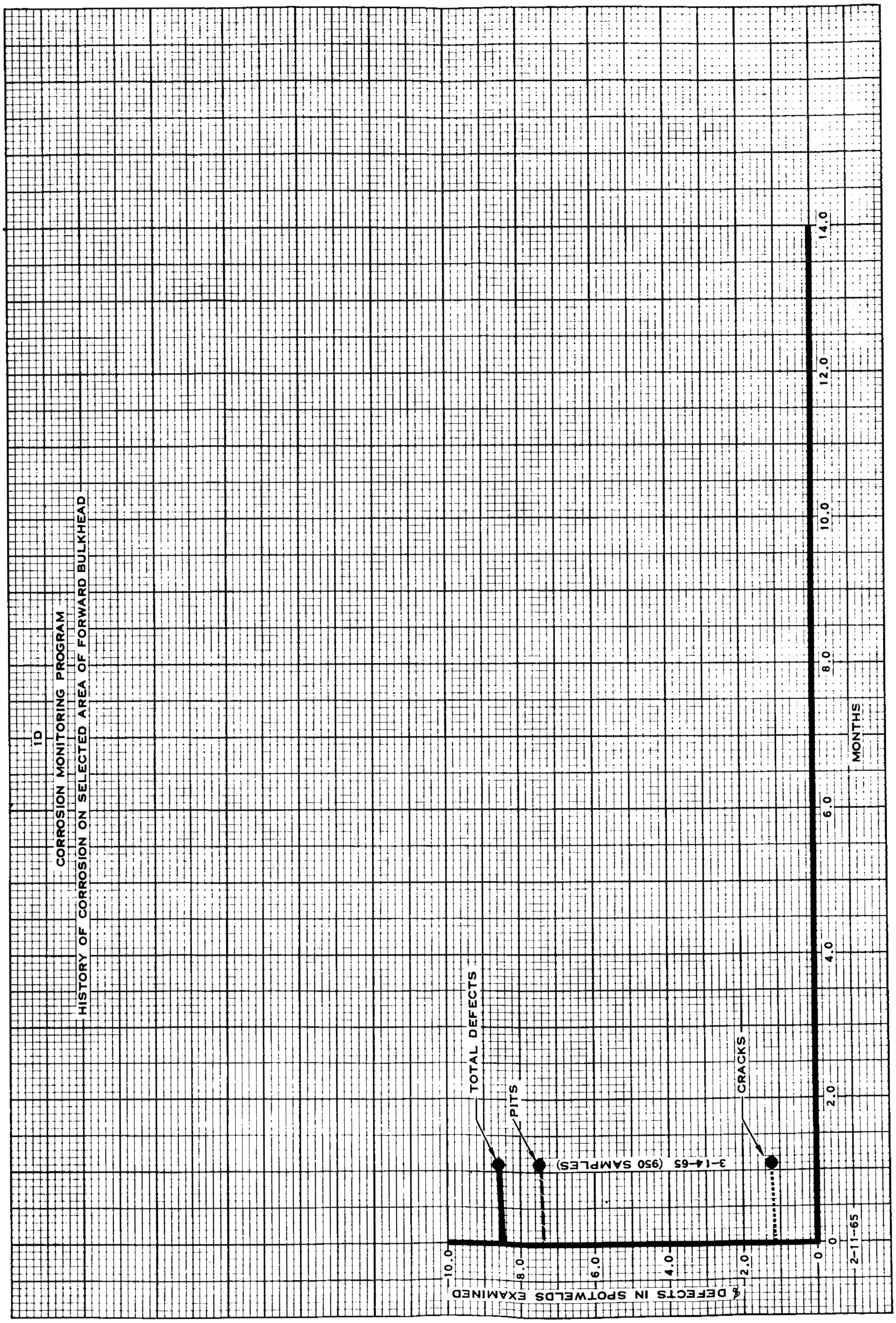

HISTORY OF CORROSION
2B TANK AFT BULKHEAD
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
11-30-62
2-1-63
PITS ONLY
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

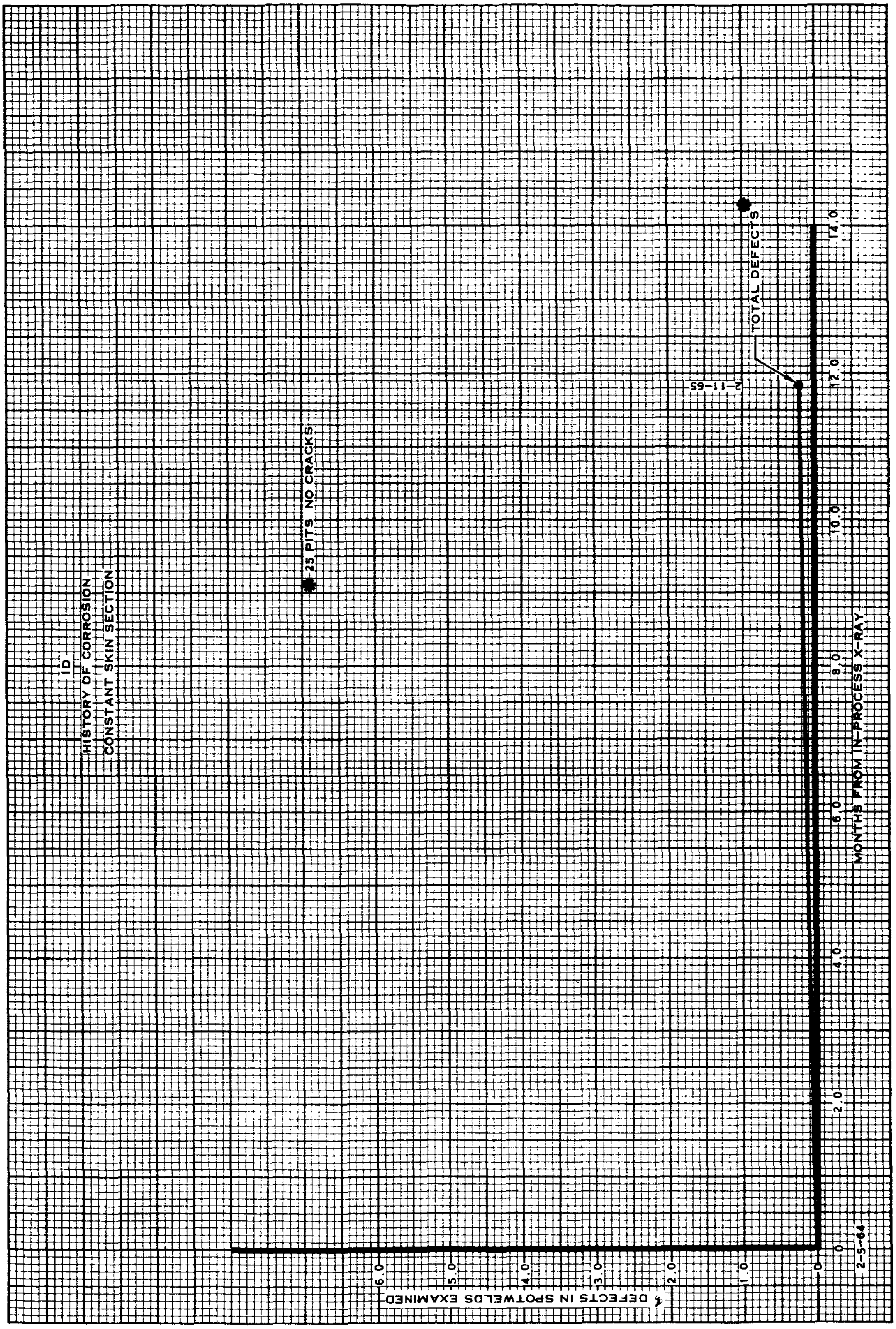

HISTORY OF CORROSION
1C TANK FORWARD BULKHEAD
1 PIT 5 CRACKS
5-4-63
2-17-63
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS FROM IN-PROCESS X-RAY
0.0
1.0
2.0
3.0
4.0
% DEFECTS IN SPOTWELDS EXAMINED

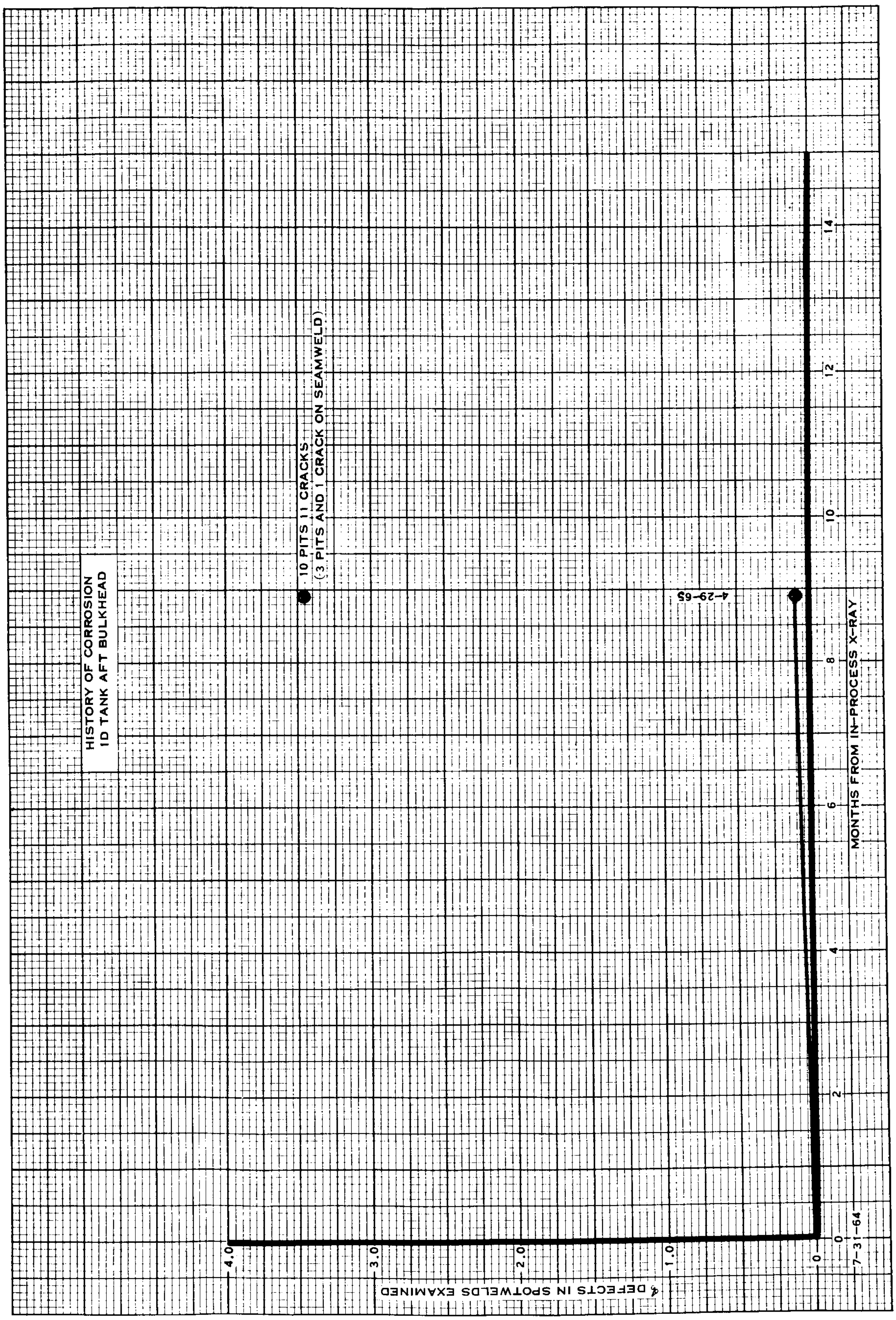

HISTORY OF CORROSION
1C TANK CONSTANT SKIN
1 5 PITS 1 CRACK
5-4-63
3-15-63
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

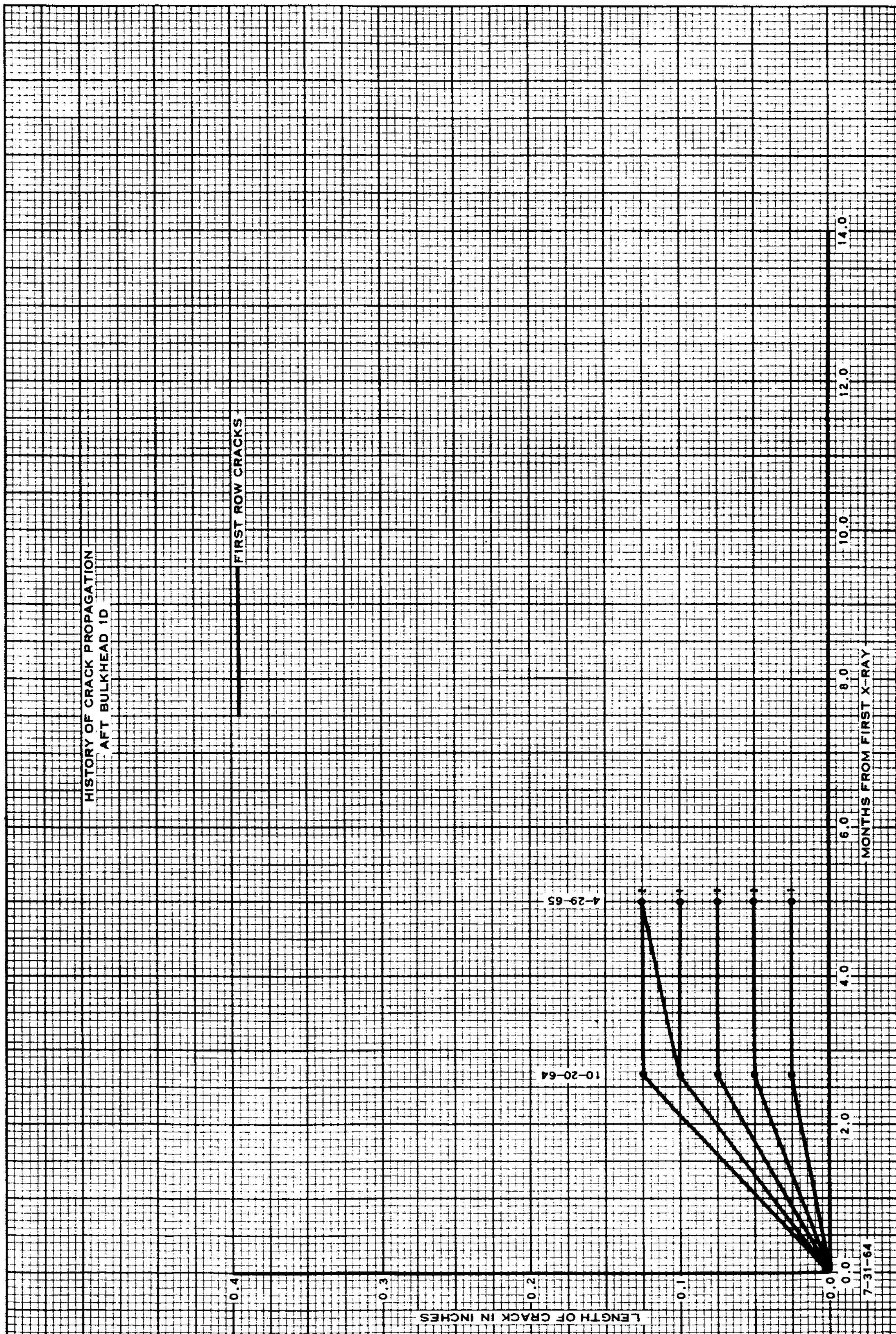

HISTORY OF CORROSION
1C TANK AFT BULKHEAD
2 PITS NO CRACKS
5-4-63
3-18-63
MONTHS FROM IN PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

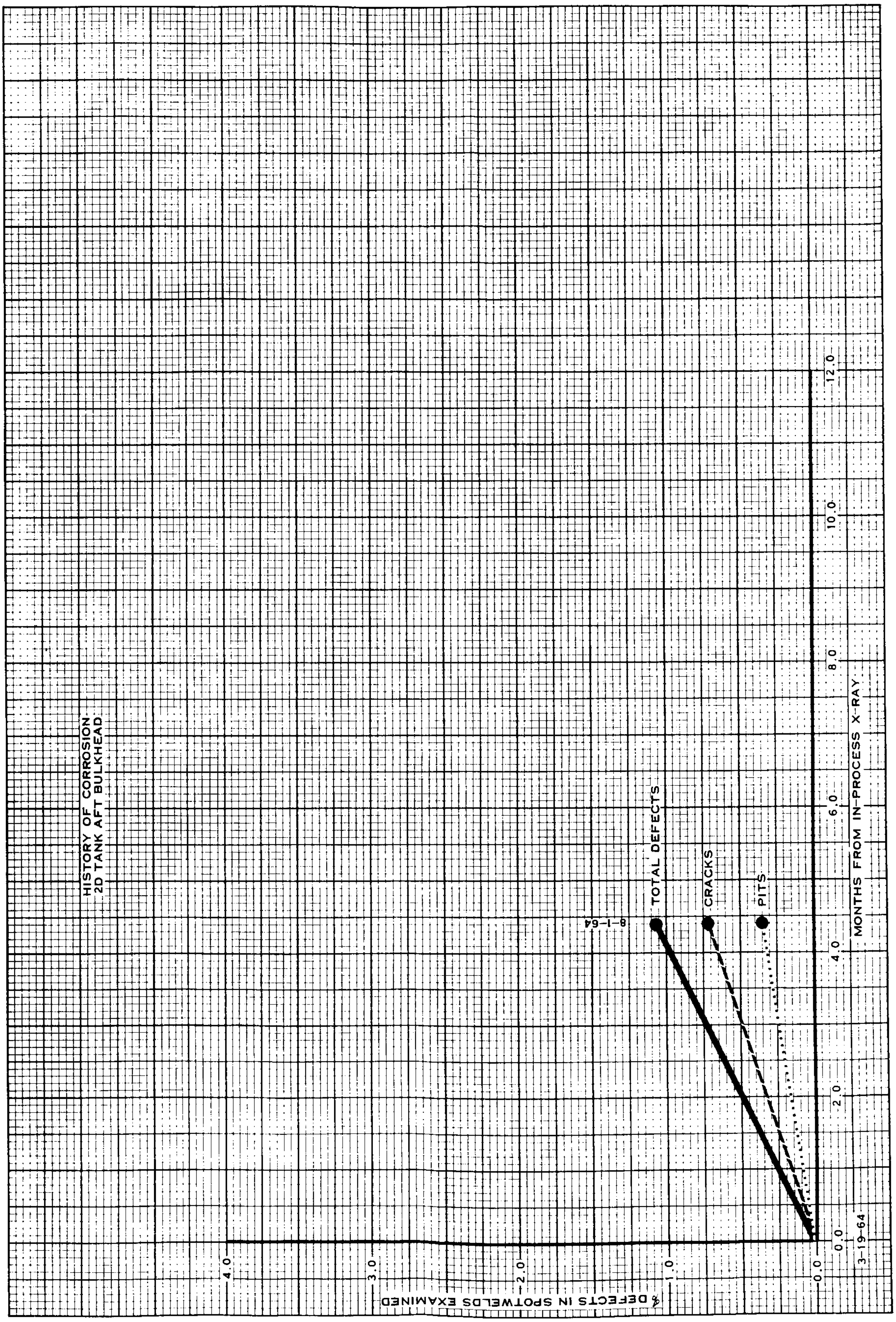

HISTORY OF CORROSION
1D TANK FORWARD BULKHEAD
TOTAL DEFECTS
PITS
CRACKS
2-11-65
8-6-64
2-10-64
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS FROM IN-PROCESS X-RAY
0.0
1.0
2.0
3.0
4.0
% DEFECTS IN SPOTWELDS EXAMINED

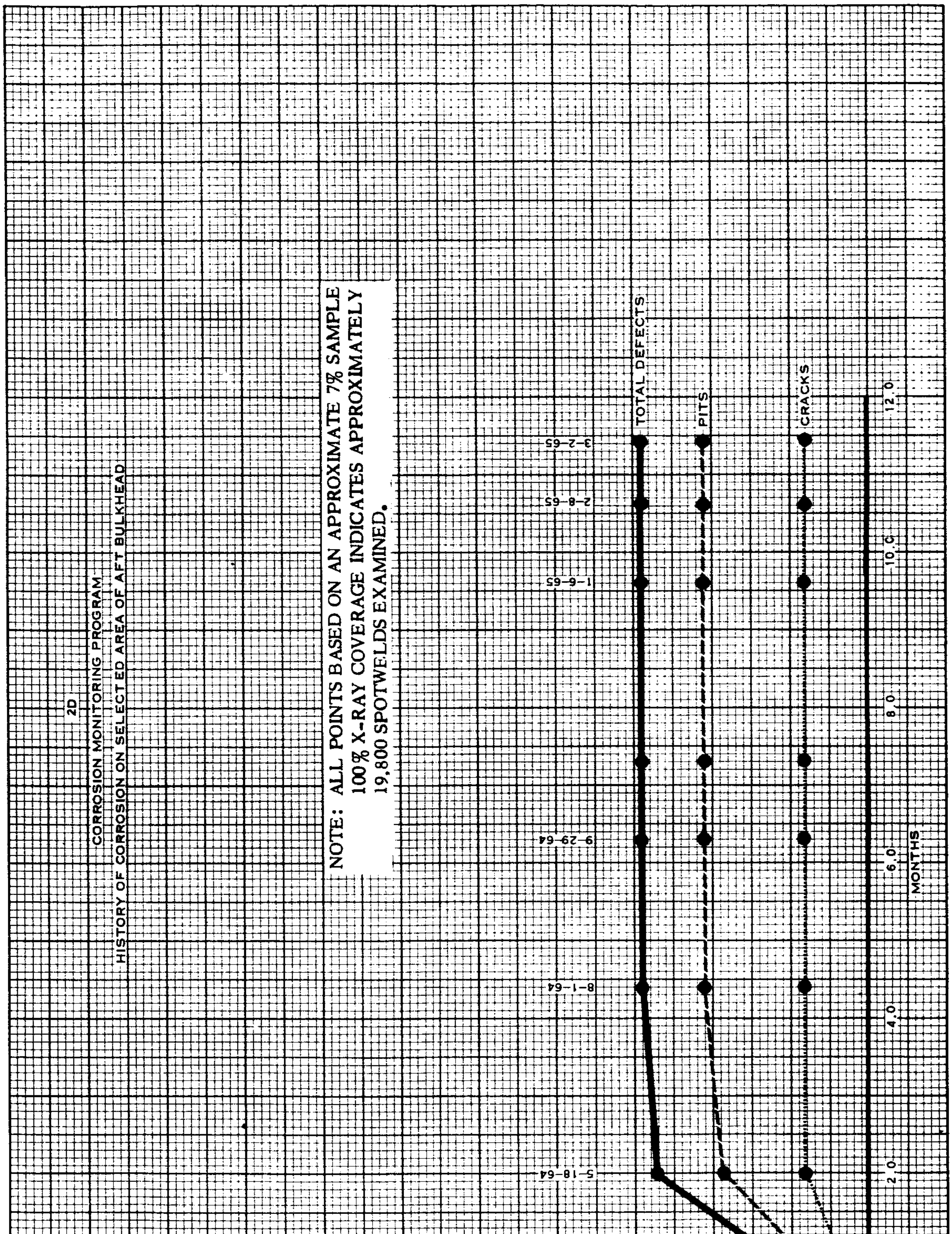

1D
CORROSION MONITORING PROGRAM
HISTORY OF CORROSION ON SELECTED AREA OF FORWARD BULKHEAD
TOTAL DEFECTS
PITS
CRACKS
3-14-65 (950 SAMPLES)
% DEFECTS IN SPOTWELDS EXAMINED
10.0
8.0
6.0
4.0
2.0
0
MONTHS
2-11-65
2.0
4.0
6.0
8.0
10.0
12.0
14.0

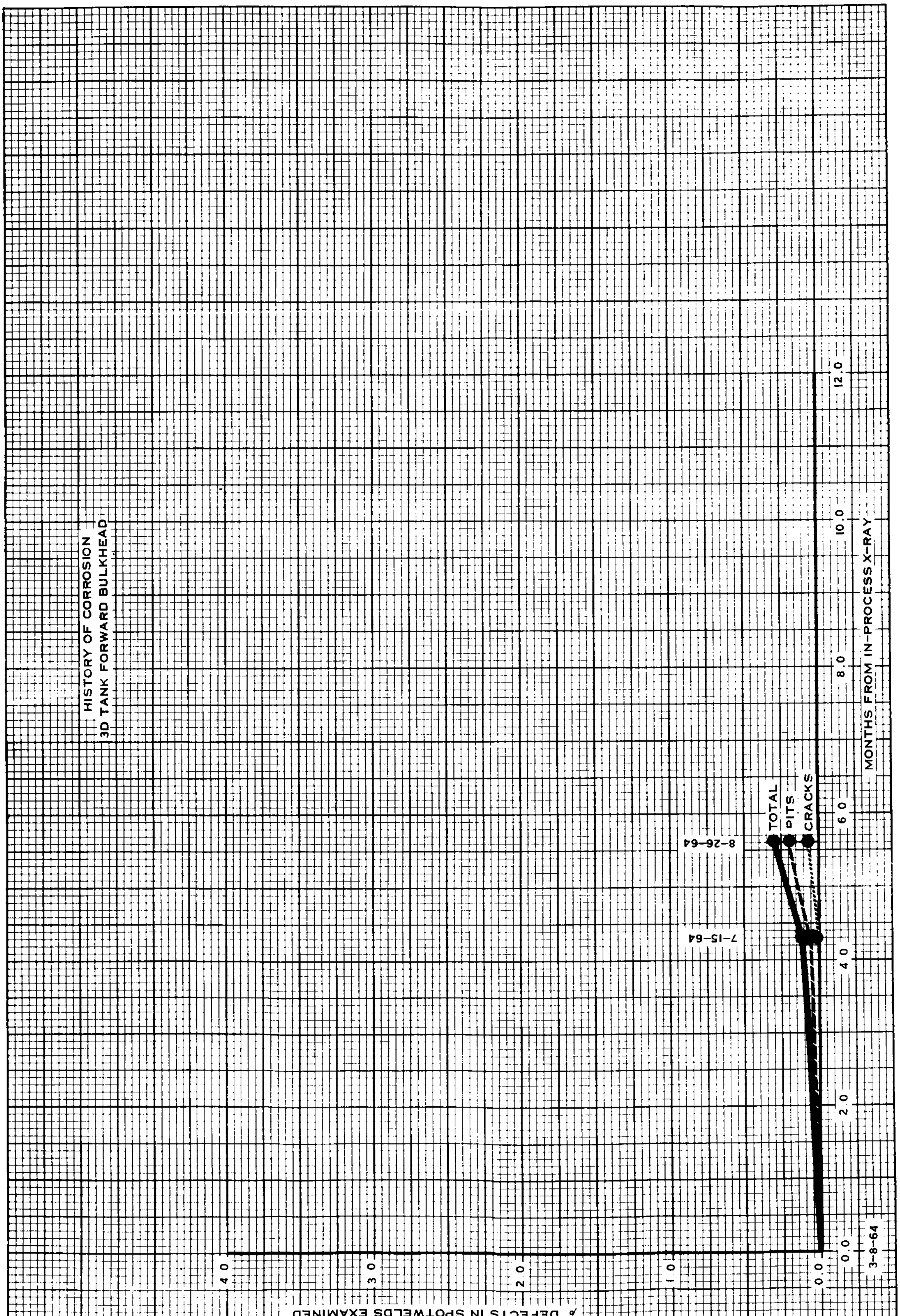

1D
HISTORY OF CORROSION
CONSTANT SKIN SECTION
25 PITS NO CRACKS
TOTAL DEFECTS
2-11-65
% DEFECTS IN SPOTWELDS EXAMINED
0
1.0
2.0
3.0
4.0
5.0
6.0
MONTHS FROM IN-PROCESS X-RAY
0
2-5-64
2.0
4.0
6.0
8.0
10.0
12.0
14.0

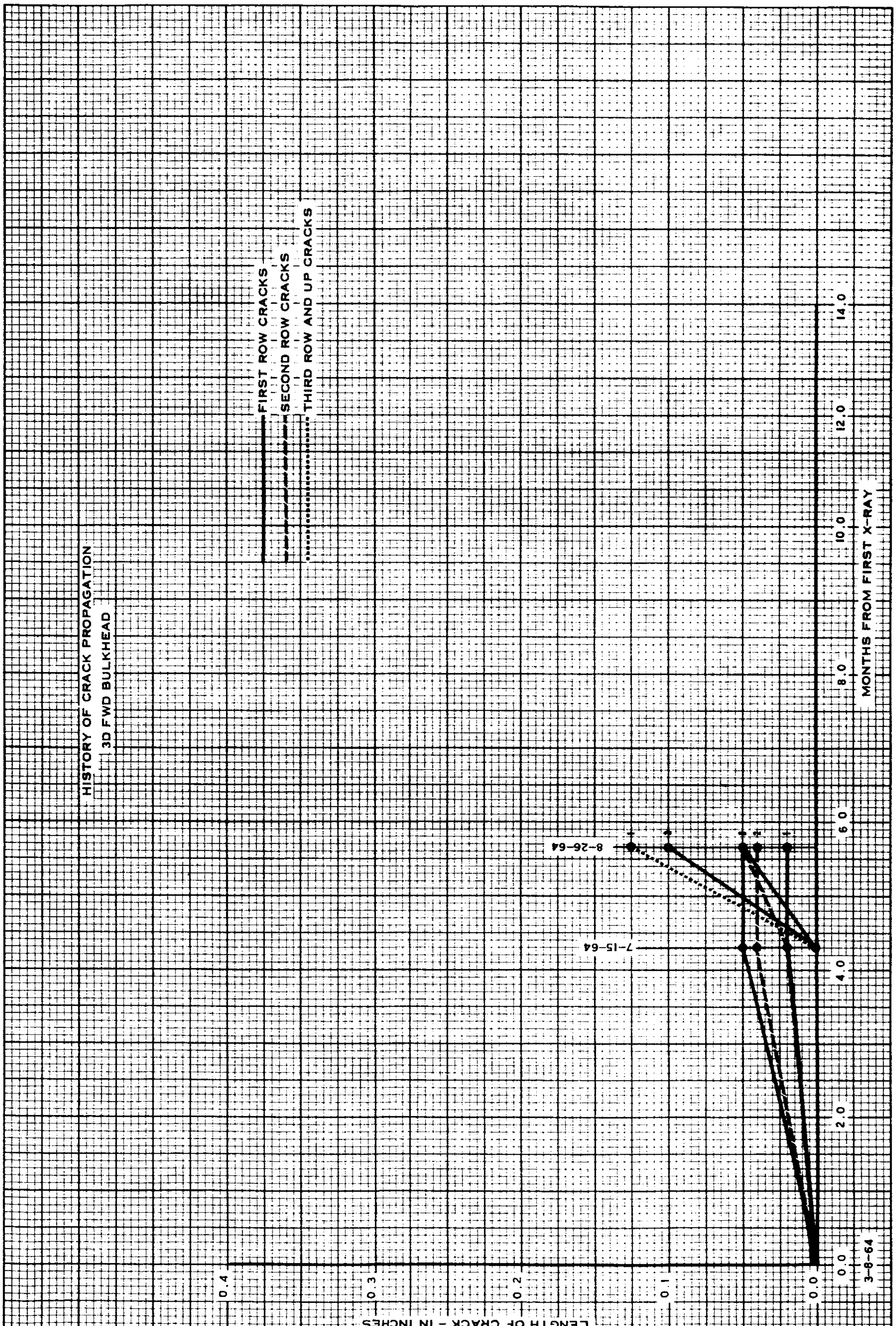

HISTORY OF CORROSION
1D TANK AFT BULKHEAD
10 PITS 11 CRACKS
(3 PITS AND 1 CRACK ON SEAMWELD)
4-29-65
MONTHS FROM IN-PROCESS X-RAY
0
7-31-64
2
4
6
8
10
12
14
% DEFECTS IN SPOTWELDS EXAMINED
0
1.0
2.0
3.0
4.0

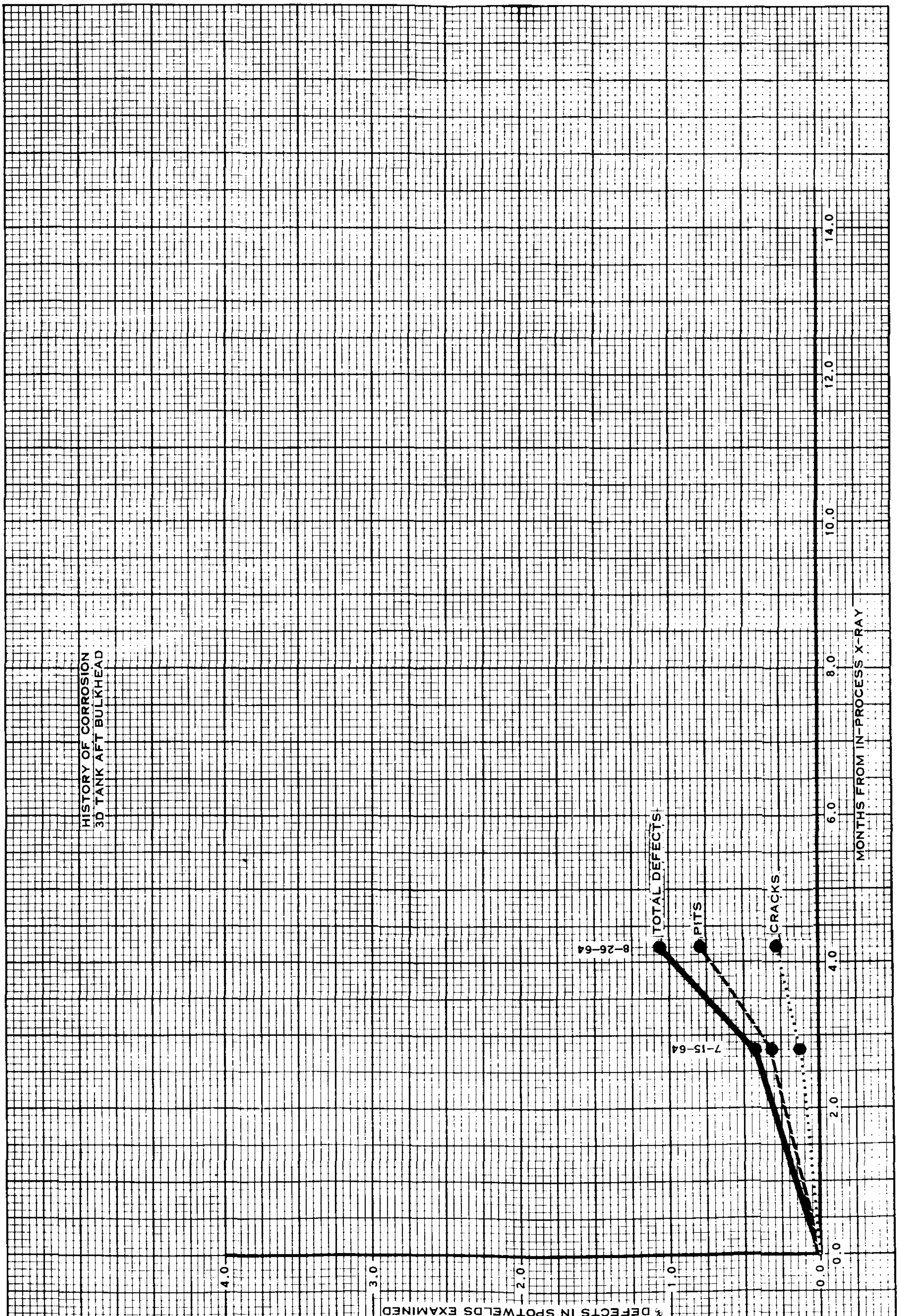

HISTORY OF CRACK PROPAGATION
AFT BULKHEAD 1D
FIRST ROW CRACKS
LENGTH OF CRACK IN INCHES
0.0
0.1
0.2
0.3
0.4
MONTHS FROM FIRST X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
7-31-64
10-20-64
4-29-65

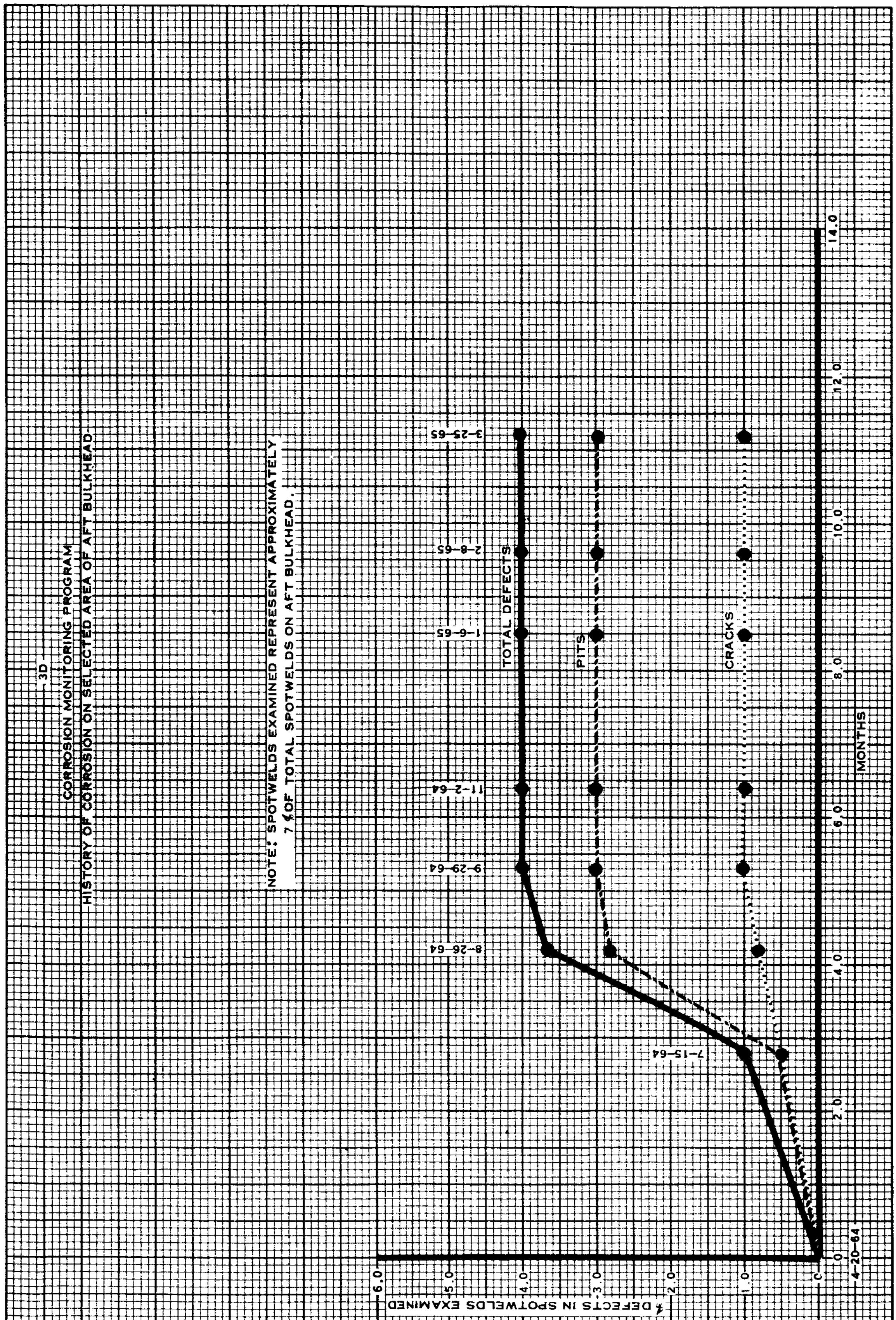

HISTORY OF CORROSION
2D TANK AFT BULKHEAD
TOTAL DEFECTS
CRACKS
PITS
8-1-64
3-19-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

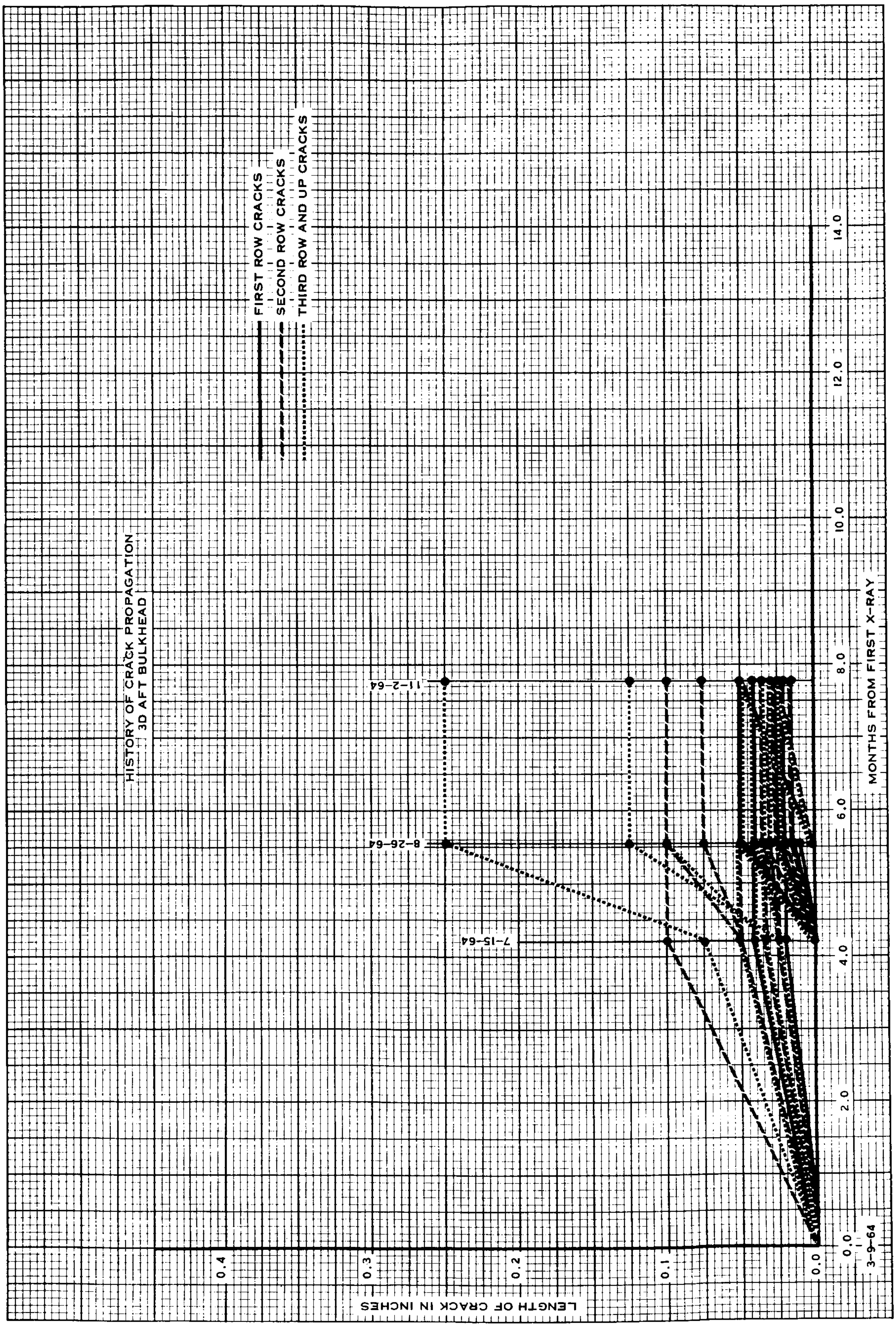

2D
CORROSION MONITORING PROGRAM
HISTORY OF CORROSION ON SELECTED AREA OF AFT BULKHEAD
NOTE: ALL POINTS BASED ON AN APPROXIMATE 7% SAMPLE
100% X-RAY COVERAGE INDICATES APPROXIMATELY
19,800 SPOTWELDS EXAMINED.
TOTAL DEFECTS
PITS
CRACKS
3-19-64
5-18-64
8-1-64
9-29-64
1-6-65
2-8-65
3-2-65
0
2.0
4.0
6.0
8.0
10.0
12.0
MONTHS
% DEFECTS IN SPOTWELDS EXAMINED
0
1.0
2.0
3.0
4.0
5.0

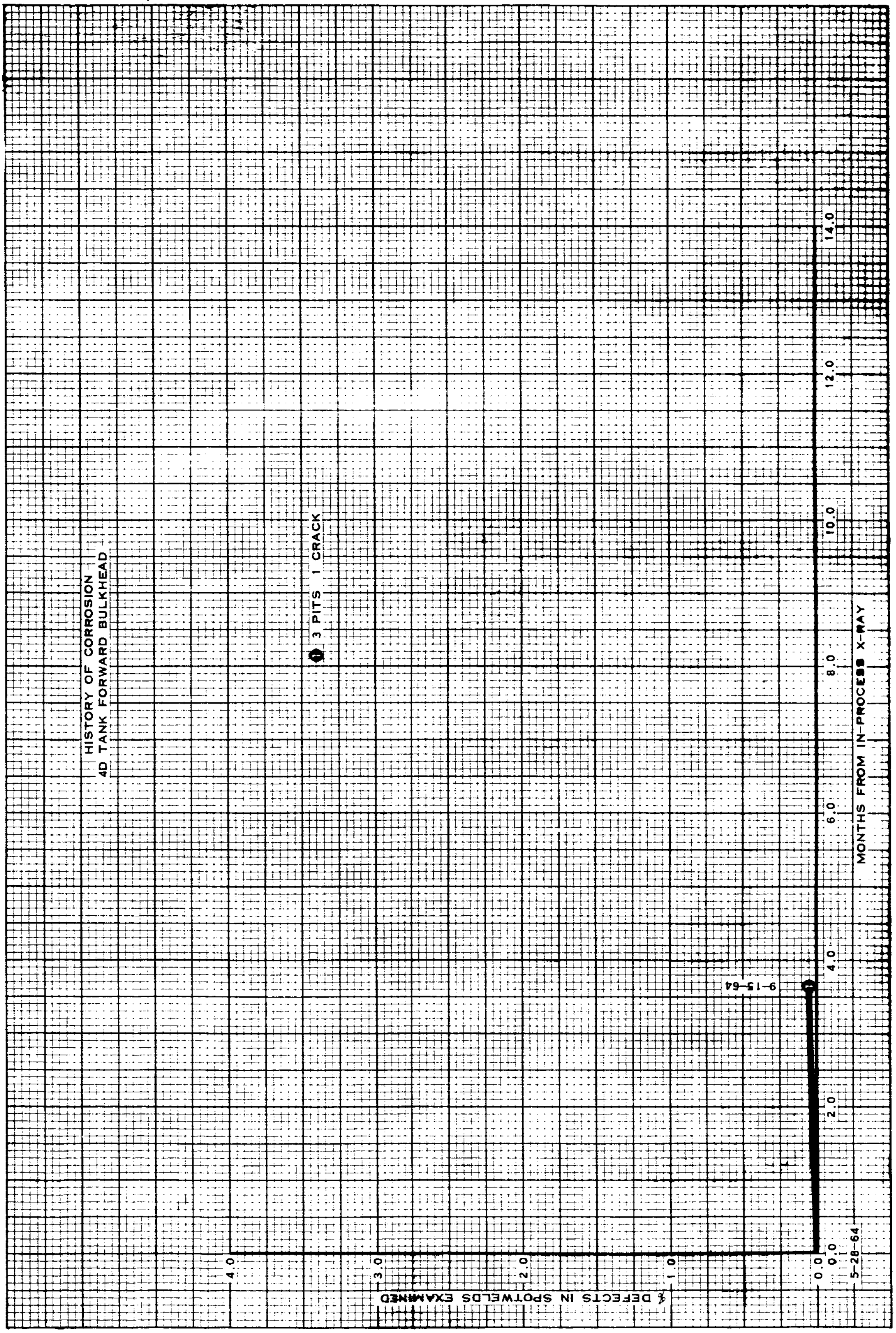

HISTORY OF CORROSION
3D TANK FORWARD BULKHEAD
TOTAL
PITS
CRACKS
8-26-64
7-15-64
3-8-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

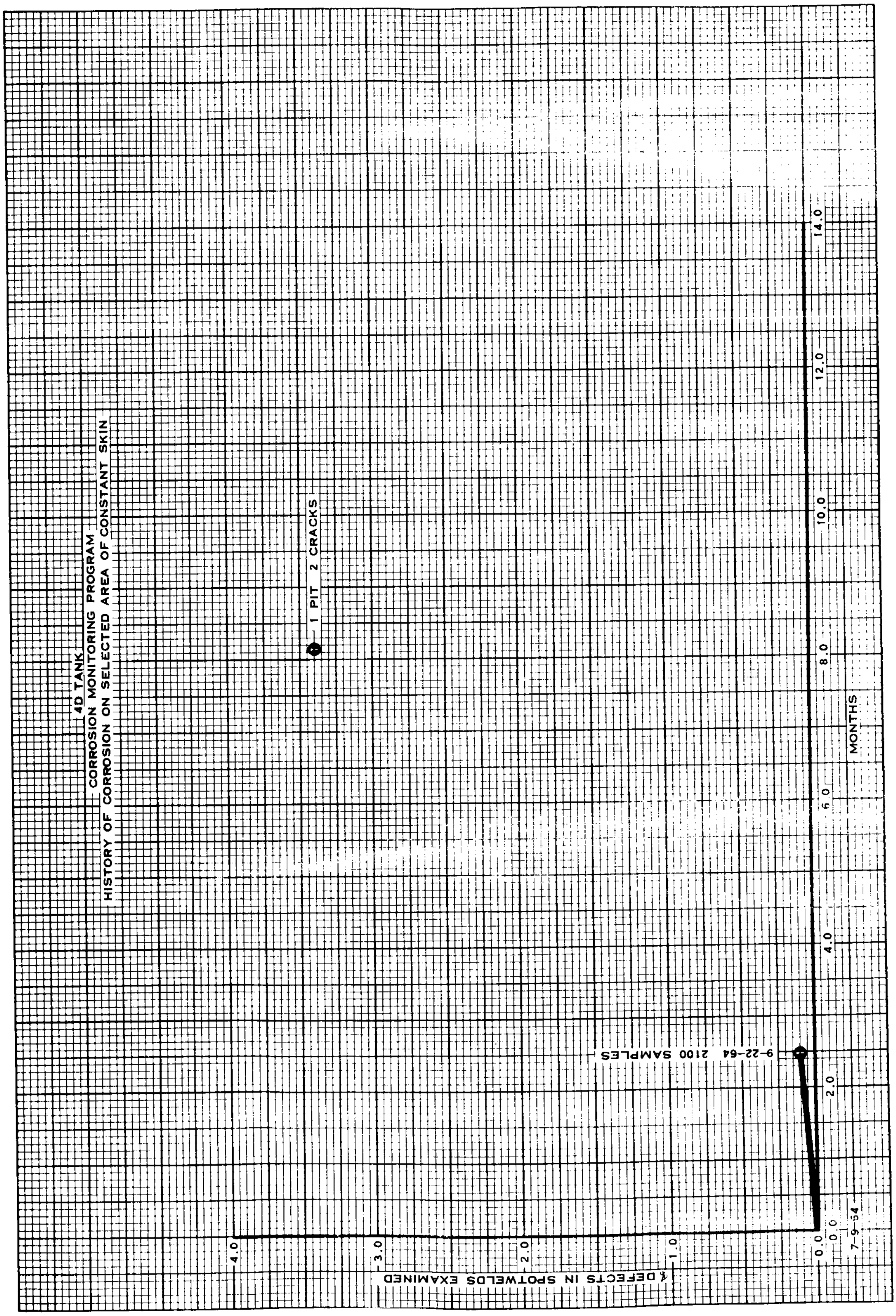

HISTORY OF CRACK PROPAGATION
3D FWD BULKHEAD
FIRST ROW CRACKS
SECOND ROW CRACKS
THIRD ROW AND UP CRACKS
MONTHS FROM FIRST X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
3-8-64
7-15-64
8-26-64
LENGTH OF CRACK - IN INCHES
0.0
0.1
0.2
0.3
0.4

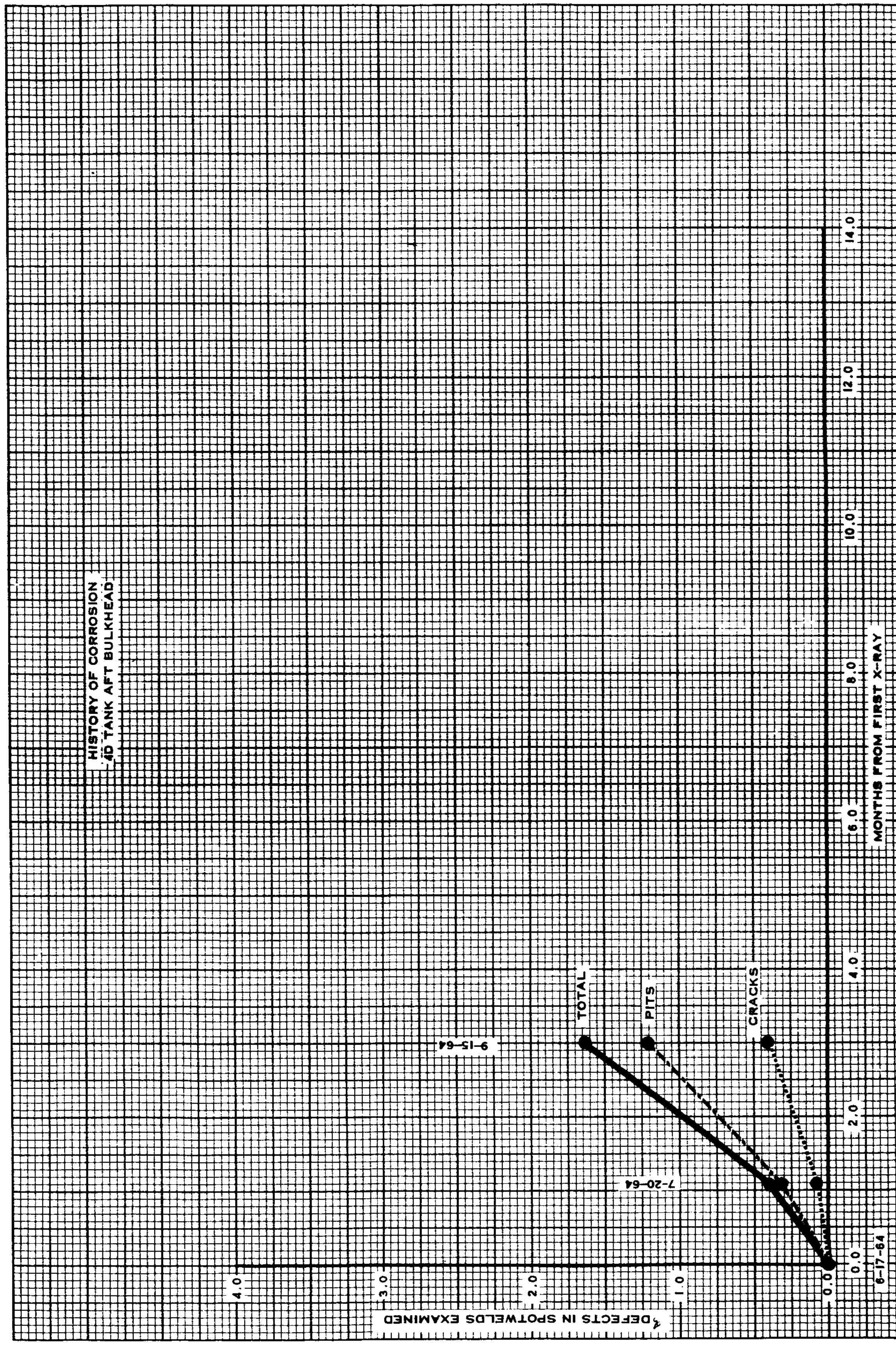

HISTORY OF CORROSION
3D TANK AFT BULKHEAD
MONTHS FROM IN-PROCESS X-RAY
% DEFECTS IN SPOTWELDS EXAMINED
TOTAL DEFECTS
PITS
CRACKS
8-26-64
7-15-64
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.0
1.0
2.0
3.0
4.0

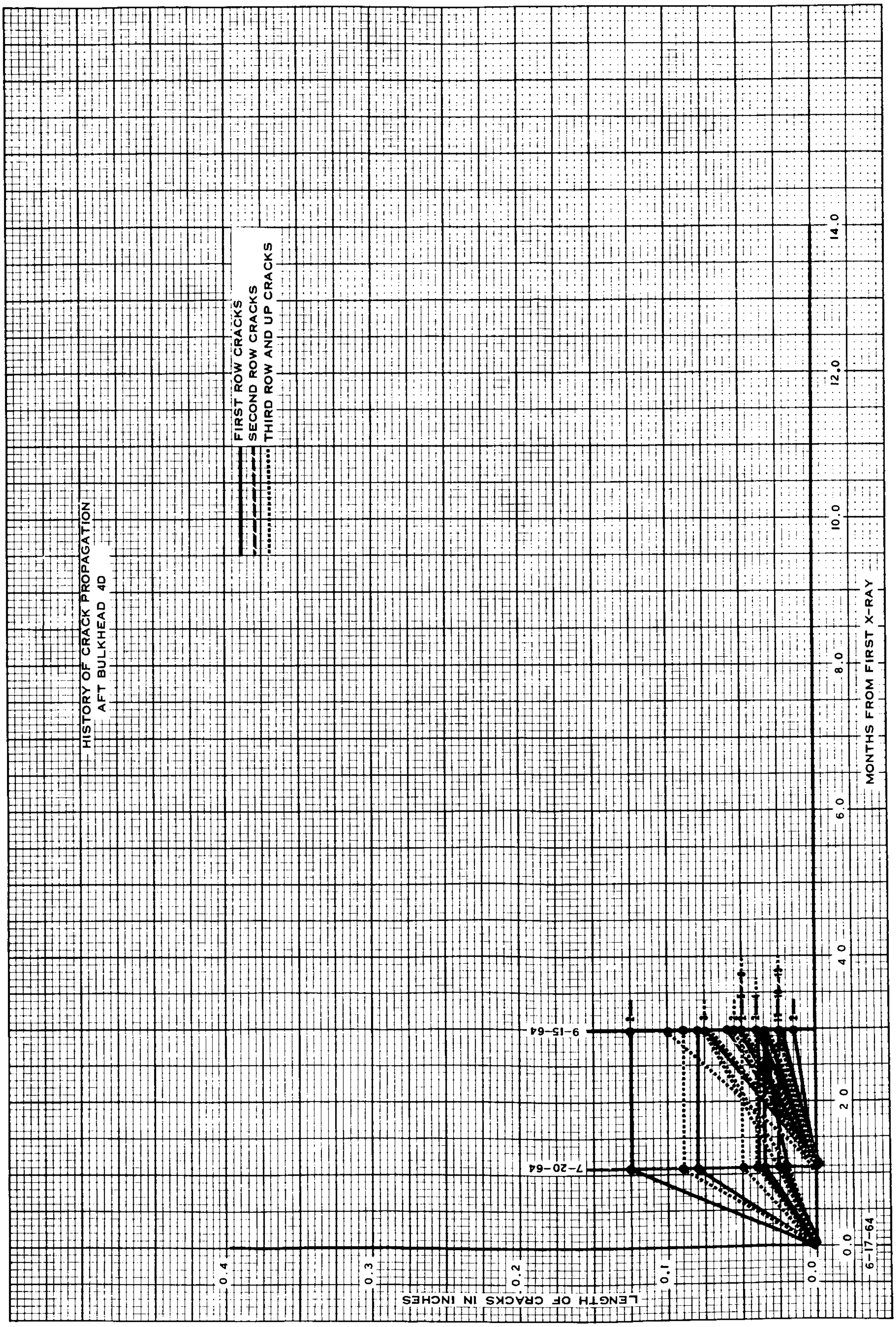

3D
CORROSION MONITORING PROGRAM
HISTORY OF CORROSION ON SELECTED AREA OF AFT BULKHEAD
NOTE: SPOTWELDS EXAMINED REPRESENT APPROXIMATELY
7% OF TOTAL SPOTWELDS ON AFT BULKHEAD.
TOTAL DEFECTS
PITS
CRACKS
4-20-64
7-15-64
8-26-64
9-29-64
11-2-64
1-6-65
2-8-65
3-25-65
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS
0
1.0
2.0
3.0
4.0
5.0
6.0
% DEFECTS IN SPOTWELDS EXAMINED

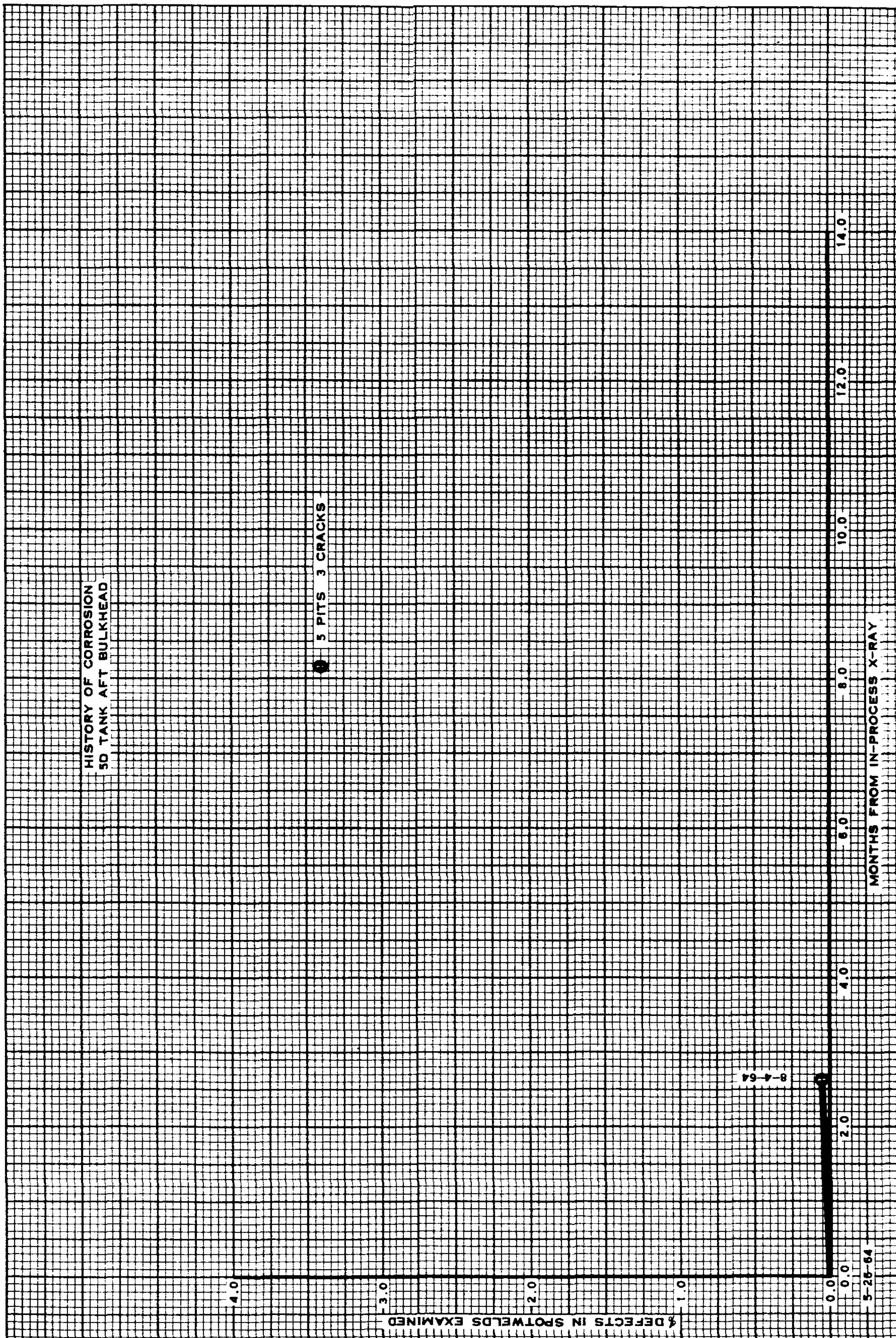

HISTORY OF CRACK PROPAGATION
3D AFT BULKHEAD
FIRST ROW CRACKS
SECOND ROW CRACKS
THIRD ROW AND UP CRACKS
11-2-64
8-26-64
7-15-64
3-9-64
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS FROM FIRST X-RAY
0.0
0.1
0.2
0.3
0.4
LENGTH OF CRACK IN INCHES

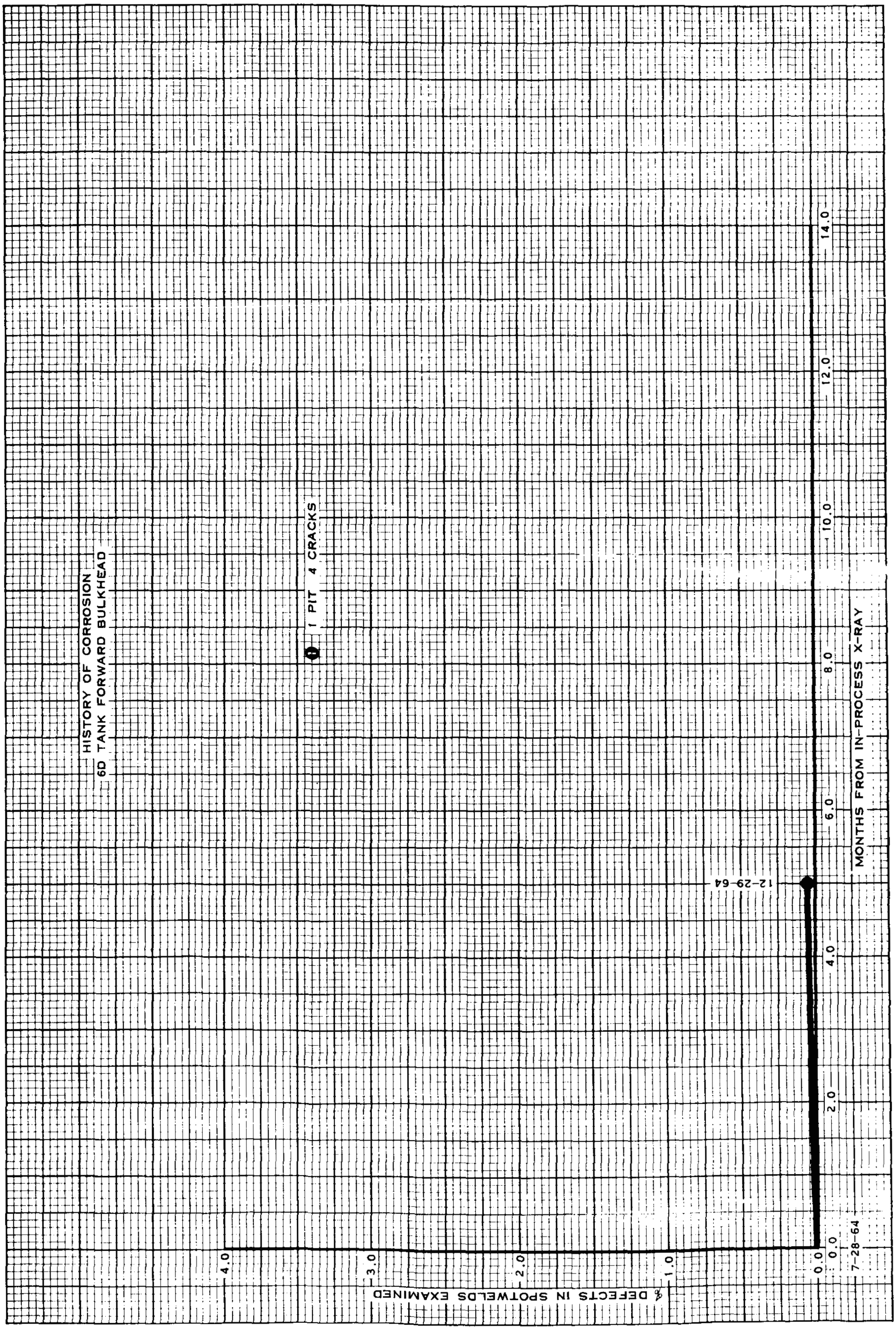

HISTORY OF CORROSION
4D TANK FORWARD BULKHEAD
3 PITS 1 CRACK
9-15-64
5-28-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0

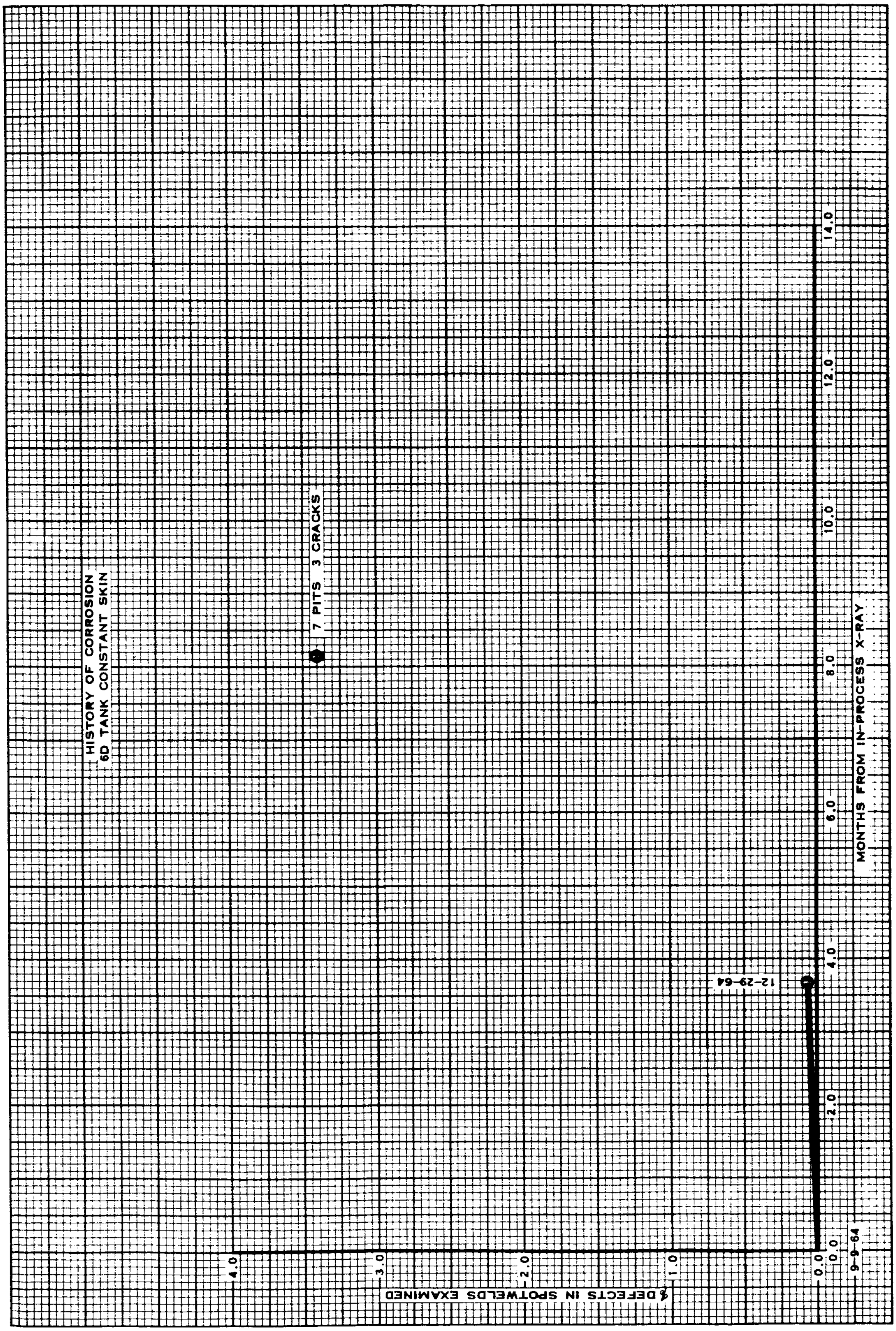

4D TANK
CORROSION MONITORING PROGRAM
HISTORY OF CORROSION ON SELECTED AREA OF CONSTANT SKIN
1 PIT 2 CRACKS
9-22-64 2100 SAMPLES
7-9-64
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS
0.0
1.0
2.0
3.0
4.0
% DEFECTS IN SPOTWELDS EXAMINED

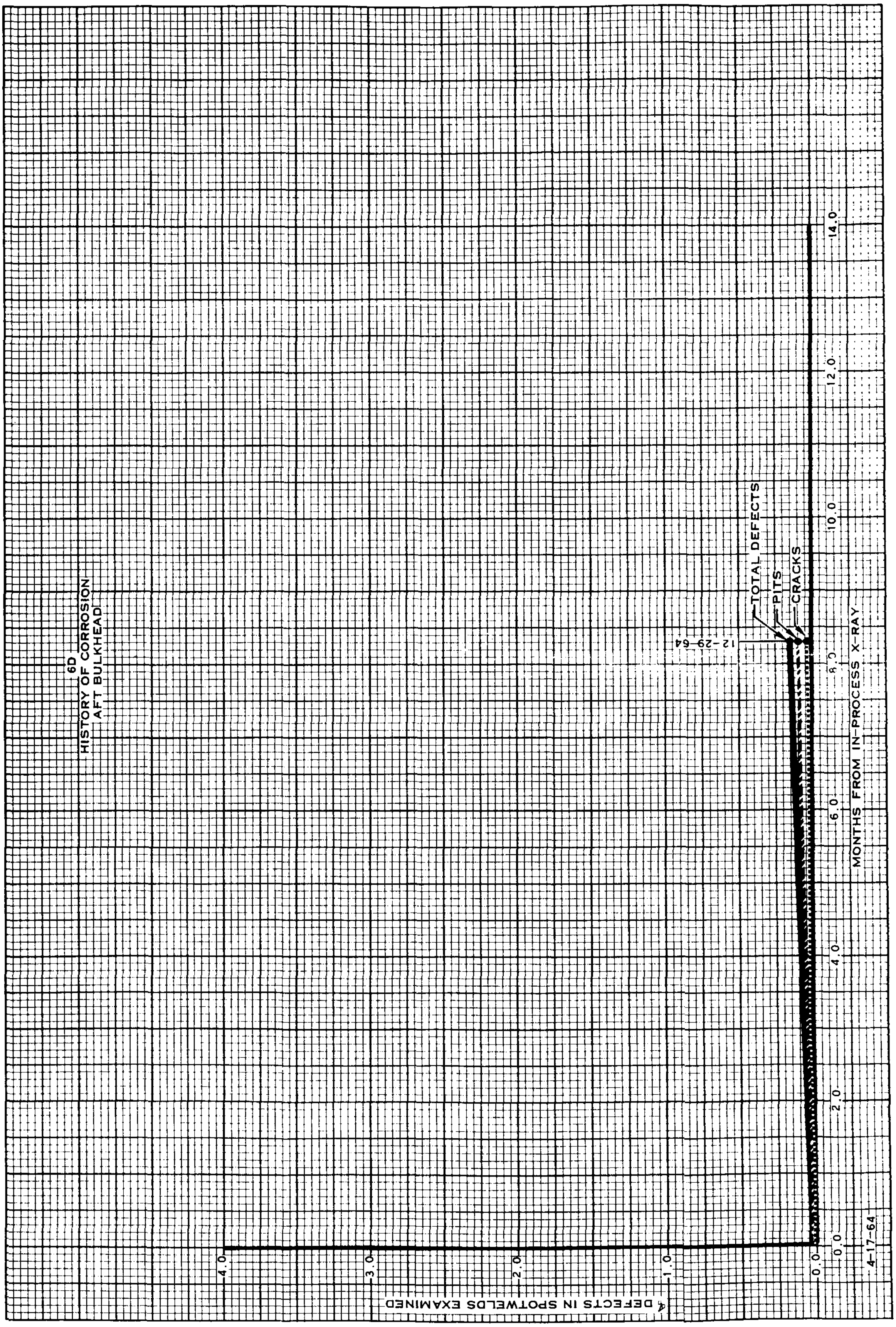

HISTORY OF CORROSION
4D TANK AFT BULKHEAD
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0
MONTHS FROM FIRST X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
6-17-64
7-20-64
9-15-64
TOTAL
PITS
CRACKS

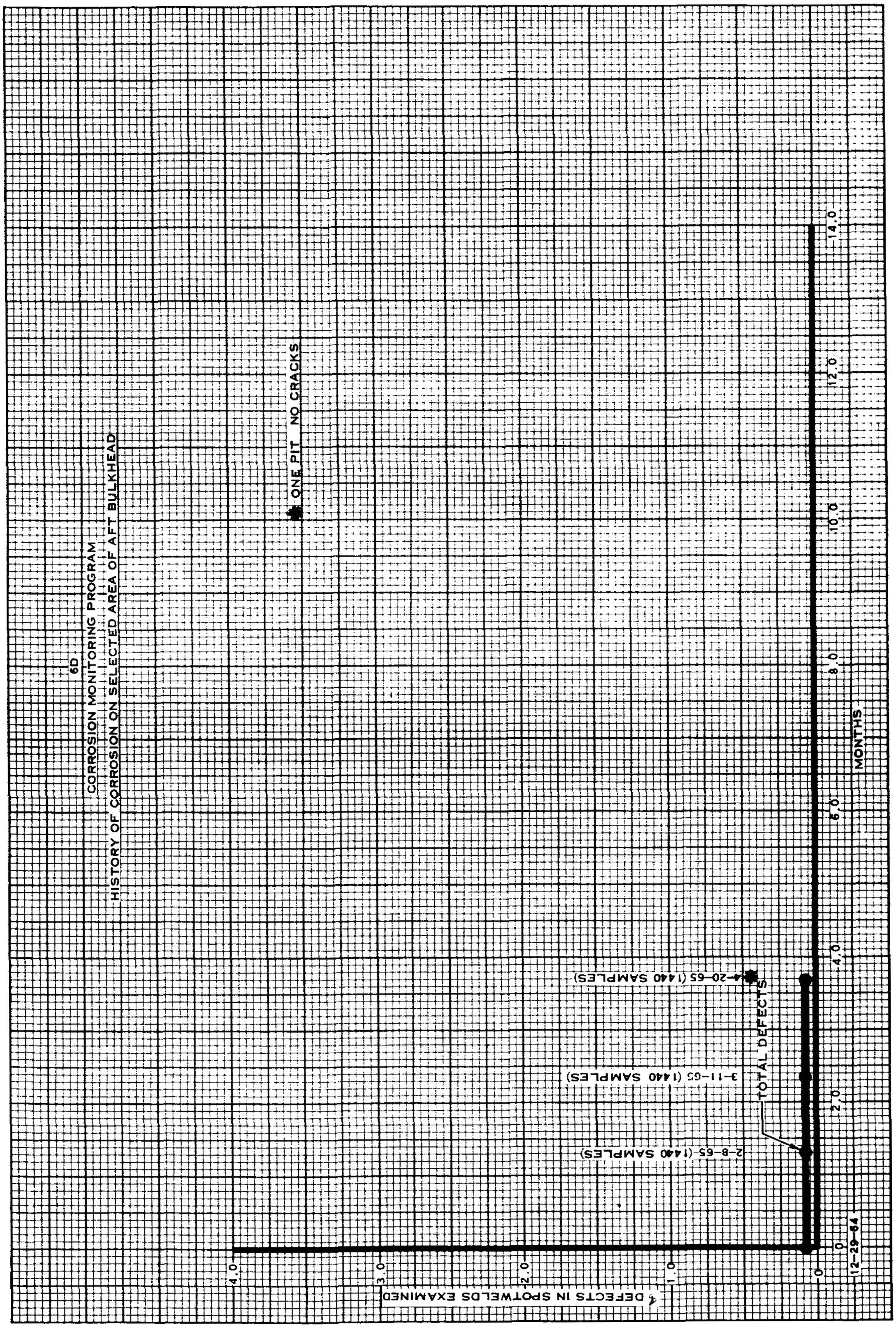

HISTORY OF CRACK PROPAGATION
AFT BULKHEAD 4D
FIRST ROW CRACKS
SECOND ROW CRACKS
THIRD ROW AND UP CRACKS
MONTHS FROM FIRST X-RAY
LENGTH OF CRACKS IN INCHES
0.0
0.1
0.2
0.3
0.4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
6-17-64
7-20-64
9-15-64

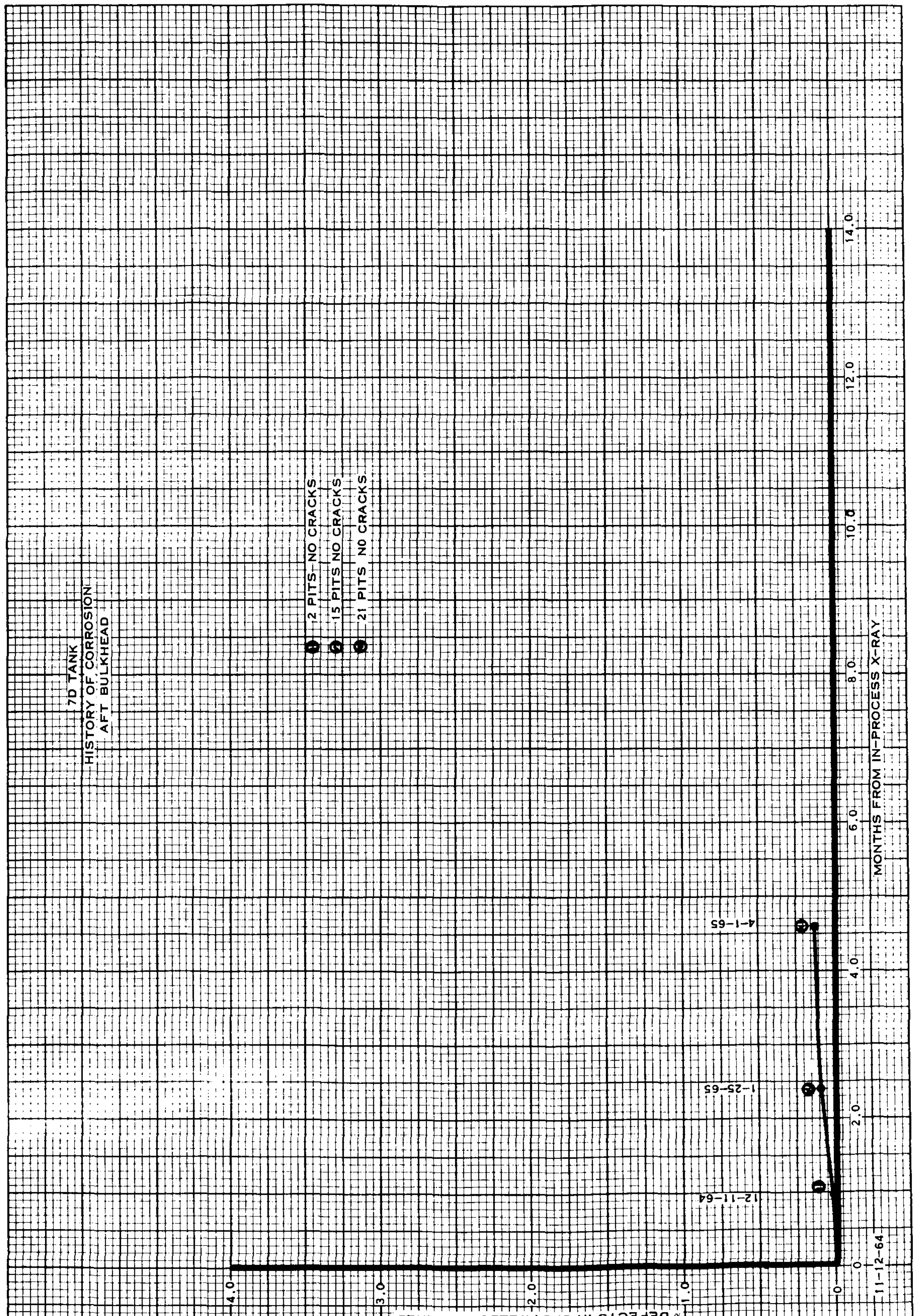

HISTORY OF CORROSION
5D TANK AFT BULKHEAD
5 PITS 3 CRACKS
8-4-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
5-26-64
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0


HISTORY OF CORROSION
6D TANK FORWARD BULKHEAD
1 PIT 4 CRACKS
12-29-64
7-28-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0


HISTORY OF CORROSION
6D TANK CONSTANT SKIN
7 PITS 3 CRACKS
12-29-64
9-9-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0


6D
HISTORY OF CORROSION
AFT BULKHEAD
TOTAL DEFECTS
PITS
CRACKS
12-29-64
4-17-64
MONTHS FROM IN-PROCESS X-RAY
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
% DEFECTS IN SPOTWELDS EXAMINED
0.0
1.0
2.0
3.0
4.0


6D
CORROSION MONITORING PROGRAM
HISTORY OF CORROSION ON SELECTED AREA OF AFT BULKHEAD
ONE PIT NO CRACKS
4-20-65 (1440 SAMPLES)
3-11-65 (1440 SAMPLES)
2-8-65 (1440 SAMPLES)
TOTAL DEFECTS
% DEFECTS IN SPOTWELDS EXAMINED
4.0
3.0
2.0
1.0
0
0
12-29-64
2.0
4.0
6.0
8.0
10.0
12.0
14.0
MONTHS


7D TANK
HISTORY OF CORROSION
AFT BULKHEAD
1 2 PITS NO CRACKS
2 15 PITS NO CRACKS
3 21 PITS NO CRACKS
MONTHS FROM IN-PROCESS X-RAY
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
11-12-64
12-11-64
1-25-65
4-1-65
% DEFECTS IN SPOTWELDS EXAMINED
0
1.0
2.0
3.0
4.0

GENERAL DYNAMICS

Convair Division